INDEX FOR APPENDIX

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/382,702	08/24/1999	PETER ANTHONY HOCHSTEIN	65.016-046	5578

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EXAMINER	
VU, BAO Q	
ART UNIT	PAPER NUMBER
2838	

DATE MAILED: 09/04/2003

FINAL 11-04-03 (12-04-03)

Please find below and/or attached an Office communication concerning this application or proceeding.

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Office Action Summary	Application No.	Applicant(s)
	09/382,702	HOCHSTEIN, PETER ANTHONY
	Examiner	Art Unit
	Bao Q. Vu	2836

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on ______ .

2a)☒ This action is FINAL. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 3,7-35,37,38 and 40-45 is/are pending in the application.

4a) Of the above claim(s) ______ is/are withdrawn from consideration.

5)☐ Claim(s) ______ is/are allowed.

6)☒ Claim(s) 3, 7-35, 37, 38, 40-45 is/are rejected.

7)☐ Claim(s) ______ is/are objected to.

8)☐ Claim(s) ______ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on ______ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

11)☐ The proposed drawing correction filed on ______ is: a)☐ approved b)☐ disapproved by the Examiner.

If approved, corrected drawings are required in reply to this Office action.

12)☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. §§ 119 and 120

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. ______ .

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

14)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).

a) ☐ The translation of the foreign language provisional application has been received.

15)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449) Paper No(s) ______ .
4) ☐ Interview Summary (PTO-413) Paper No(s). ______ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other:

DETAILED ACTION

Reissue Applications

1. The reissue oath/declaration filed with this application is defective because it fails to contain the statement required under 37 CFR 1.175(a)(1) as to applicant's belief that the original patent is wholly or partly inoperative or invalid. See 37 CFR 1.175(a)(1) and see MPEP § 1414. Applicant needs a Statement similar to the statements below:

A STATEMENT THAT THE APPLICANT BELIEVES THE ORIGINAL PATENT TO BE WHOLLY OR PARTLY INOPERATIVE OR INVALID BY REASON OF A DEFECTIVE SPECIFICATION OR DRAWING, OR BY REASON OF THE PATENTEE CLAIMING MORE OR LESS THAN PATENTEE HAD THE RIGHT TO CLAIM IN THE PATENT.

For example: "Applicant believes the original patent to be partly inoperative or invalid by reason of the patentee claiming more or less than patentee had the right to claim in the patent."

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the

invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

3. Claims 24-35, 37, 38, and 40-44 are rejected under 35 U.S.C. 103(x) as being unpatentable over Johnson (USP 5,463,280) in view of Power Supply Cookbook and the Motorola data sheet for the MC 34261 controller in view of Applicant Prior Art (APA) and in view of Hildebrand (USP 5,075,601).

Johnson discloses the claimed invention (see figure 8) an AC input (102), a rectifier (108), a switching power supply (106) except for the use of electromagnetic interference filter for use in the art of power light emitting diodes (LED's), the use of series-parallel LED array and for their use in traffic, pedestrian or rail crossing signal housing. The Power Supply Cookbook and the Motorola data sheet for the MC 34261 controller discloses that it is known in the art to use an electromagnetic interference filter for use with a switching power supply. It would have been obvious to one having ordinary skill in the art at the time of the invention was made to modify the power supply assembly as taught by Johnson and use an electromagnetic filter (EMI) with the switching power supply as taught by the Power Supply Cookbook and the Motorola data sheet for the MC 34261 controller since the Power Supply Cookbook teaches that the electromagnetic filter (EMI) is crucial or essential element in any power factor correction circuitry.

Applicant's Prior Art (APA) in view of Hildebrand discloses that it is known in the art to make use of series-parallel LED array in a switching power supply and for their use in traffic, pedestrian or rail crossing signal housing.

It would have been obvious to one having ordinary skill in the art at the time of the invention was made to modify the LED array as taught by Johnson, The Power Supply Cookbook and the Motorola data sheet and use the series- parallel LED array string having different current paths, (clearly shown in applicant's prior art figure 1), and for their use in traffic, pedestrian or rail crossing signal housing, since APA teaches that use of these LED arrays provides a greater benefit than the less inefficient incandescent lamps and has the added feature of a more reliable operation of the LED array, this feature highly desirable for their use in traffic, pedestrian or rail crossing signals housing.

Johnson in view of Power Supply Cookbook and Motorola data sheet and in view of Applicant's Prior Art (APA) discloses the claimed invention except for the use of a conflict monitor circuit used to help control leakage currents by providing high impedance if such conditions exists.

Hildebrand discloses that it is known in the art to provide the use of an adaptive clamp circuit used to help control leakage currents by providing high impedance if such conditions exists. It would have been obvious to one having ordinary skill in the art at the time of the invention was made to modify the device of Johnson in view of Power Supply Cookbook and Motorola data sheet and provide an adaptive clamp circuit as taught by Hildebrand, in order to lessen the effects of current leakage inherent to LED circuitry and have a more dynamic response to this recurring problem.

Response to Arguments

4. Applicant's arguments filed 6-18-2003 have been fully considered but they are not persuasive.

5. In response to applicant's arguments against the references individually, one cannot show nonobviousness by attacking references individually where the rejections are based on combinations of references. See *In re Keller*, 642 F.2d 413, 208 USPQ 871 (CCPA 1981); *In re Merck & Co.*, 800 F.2d 1091, 231 USPQ 375 (Fed. Cir. 1986).

6. The obviousness rejection is based on five different references. (See paragraph #3 above) The features of each reference are presented in each of the following paragraphs.

First, the Johnson reference was used to teach a switching power supply with power factor correction for use with a LED array.

Second, the Power Supply Cookbook and Motorola data sheet teaches the use an electromagnetic interference filter (EMI) for use with power factor correction in a switching power supply.

Third, Applicant's Prior Art (APA) illustrates that it is known in the art to make use of series-parallel LED array in a power supply circuit and for their use in traffic, pedestrian or rail crossing signal housing.

Fourth, Hildebrand was cited to show that it is known in the art to provide the use of an adaptive clamp circuit used to help control leakage currents by providing high impedance if such conditions exists.

The obviousness rejection is based a combination of these five references.

7. The Johnson reference was used to teach a switching power supply with power factor correction for use with a LED array. The Johnson reference did not teach the use of an EMI filter. The Power Supply Cookbook and Motorola data sheet teaches the use an electromagnetic interference filter (EMI) for use with power factor correction in a switching power supply.

8. The first step of the combination was take the EMI filter for its use with a power factor circuit because it is crucial or essential element in any power factor correction circuitry and combine it with the teachings of the Johnson reference.

9. The combination now teaches a switching power supply with power factor correction for use with a LED array having an EMI filter. Now the present combination does not teach that it is a series-parallel combination or used in traffic, pedestrian or rail crossing signal housing, but the Johnson reference does teach a LED array. APA teaches a series-parallel LED array combination or used in traffic, pedestrian or rail crossing signal housing in a power supply circuit.

10. The second step of the combination was made to have a series-parallel combination or used in a traffic, pedestrian or rail crossing signal housing, since it provides a more reliable and efficiency of operation as taught by APA and combine it with the teachings of Johnson and The Power Supply Cookbook and Motorola data sheet.

11. The combination now teaches a switching power supply with power factor correction for use with a LED array, being a series-parallel LED array combination or

used in traffic, pedestrian or rail crossing signal housing in a power supply circuit, that has an EMI filter. Further, now the combination is deficient with respect to the use of the conflict monitor circuit used to help control leakage current by providing high impedance if such conditions exist. Hildebrand was cited to show that it is known in the art to provide the use of an adaptive clamp circuit used to help control leakage currents by providing high impedance if such conditions exists. The Hildebrand circuit (see figure 1A) uses a Zener diode (CR5) in combination with transistor (Q2) and that those components correspond to the Zener diode (D5) and the transistor (q1) of the claimed clamp circuit's "voltage sensing means". Hildebrand circuit uses a transistor (Q3) in combination with resistor (R7) and that those components correspond to the transistor (Q2) and the resistor (R5) of the claimed clamp circuit's "control load means". Then finally, the circuit when the traffic light is off, thereby preventing leakage current, and that it completely removes this resistor (R7) from the circuit when the light is on. This operation corresponds to that of the claimed clamp circuit, which places the resistor (R5) of its "control load means" in the circuit when the light is off and then completely removes that resistor (R5) from the circuit when the light is on.

12. The final step of the combination was to take the teachings of Hildebrand of the adaptive clamp circuit used to help control leakage currents and make the final combination with APA, Johnson, The Power Supply Cookbook and Motorola data sheet.

13. In response to applicant's argument the cited references does not disclose a power supply which " maintains current and voltage wave forms substantially in phase and provides a regulated current output with respect to variations in the input line." This

feature is what power factor correction circuitry does. All current will causes losses in the supply and distribution system. A load with a power factor of 1.0 results in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system. A poor power factor can be the result of either a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or distorted/discontinuous current waveform. Poor load current phase angle is generally the result of an inductive load such as an induction motor, power transformer, lighting ballasts, welder or induction furnace. A distorted current waveform can be the result of a rectifier, variable speed drive, switched mode power supply, discharge lighting or other electronic load.

Conclusion

14. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Bao Q. Vu whose telephone number is (703) 308-2318. The examiner can normally be reached on Monday-Fridays, 8:00AM- 5:00PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Michael S. Sherry can be reached on (703) 308-1680. The fax phone number for the organization where this application or proceeding is assigned is (703) 872-9306.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (703) 308-0956.

Bao Vu

Bao Q. Vu
Primary Examiner
Art Unit 2838

August 27, 2003

PTO/SB/31 (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

NOTICE OF APPEAL FROM THE EXAMINER TO THE BOARD OF PATENT APPEALS AND INTEFERENCES

Docket Number (Optional): 65,016-046

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to "Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450" on November 3, 2003

Signature Anne L. Kubit

Typed or printed name Anne L. Kubit

In re Application of Peter Anthony Hochstein

Application Number 09/382,702

Filed 08/24/1999

For POWER SUPPLY FOR LIGHT EMITTING...

Art Unit 2838

Examiner Bao Q. Vu

Applicant hereby appeals to the Board of Patent Appeals and Interferences from the last decision of the examiner.

The fee for this Notice of Appeal is (37 CFR 1.17(b)) $ 330.00

☐ Applicant claims small entity status. See 37 CFR 1.27. Therefore, the fee shown above is reduced by half, and the resulting fee is: $ ______

☒ A check in the amount of the fee is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account. I have enclosed a duplicate copy of this sheet.

☐ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. ______. I have enclosed a duplicate copy of this sheet.

☐ A petition for an extension of time under 37 CFR 1.136(a) (PTO/SB/22) is enclosed.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

☐ applicant/inventor.

☐ assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

☒ attorney or agent of record. Registration number 22,180.

☐ attorney or agent acting under 37 CFR 1.34(a). Registration number if acting under 37 CFR 1.34(a). ______

Harold W. Milton

Signature

Harold W. Milton, Jr.

Typed or printed name

(248) 723-0352

Telephone number

November 3, 2003

Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☒ *Total of 1 forms are submitted.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Power Supply Cookbook

Marty Brown

MOTOROLA
Series in Solid State Electronics

Butterworth–Heinemann
Boston London Oxford Singapore Sydney Toronto Wellington

3. Pulsewidth Modulated Switching Power Supplies

Although pulsewidth modulated (PWM) switching power supplies have been around for a long time, it was not until the mid-1970s that they became more accepted and broadly applied. Switching power supplies offer many advantages over linear regulators, but they are also much more complicated to design.

The major advantages that can be realized over a linear power supply are a higher integration of power functions at a lower weight, and a consistently higher efficiency. The disadvantages are higher RFI emissions, and the fact that they are more difficult to design and hence require a longer design period. The designer starting his or her first complicated design (more than a board-level regulator), should expect about a seven-month design–debug period until a production-grade design can be released. This book provides a shortcut method of reducing this time by providing to the designer just the right information needed for each phase of the design.

Many of the technologies involved in the design of switching power supplies are unfamiliar to the typical design engineer. This can easily be explained by looking at the technologies being applied in modern product design. They center around microprocessors and digitizing of analog signals for use in microprocessors. Little of this technology is applicable in switching power supply design. Engineers, whether they want to or not, will learn some of these basic technologies in the process of the design. Many engineers find switching power supplies challenging and exciting, as being a peculiar combination of digital, analog, and RF. Hidden behind the schematic of every successful switching power supply are hundreds of puzzles, trade-offs, and frustrated moments.

3.1 The Fundamentals of PWM Switching Power Supplies

The operation of switching power supplies can be relatively easy to understand. Unlike linear regulators, which operate the power transistor in the linear mode, the PWM switching power supply operates the power transistors in both the saturated and cutoff states. In these states, the volt–ampere product across the power transistor is always kept low (saturated, low-V/high-I; cutoff, high-V/no-I). This product within the power device is the loss within all the power semiconductors.

This more efficient operation of the PWM switching power supply is achieved by "chopping" the direct current (dc) input voltage into pulses

whose amplitude is the magnitude of the input voltage and whose duty cycle is controlled by a switching regulator controller. Once the input voltage is converted to an ac rectangular waveform, the amplitude can be stepped up or down by a transformer. Additional output voltages can be derived by adding secondaries to the transformer. Ultimately these ac waveforms are then filtered to provide the dc output voltages.

The controller, whose main purpose is to maintain a regulated output voltage, operates very much like a linear-style controller. That is, the functional blocks, voltage reference, and error amplifier are arranged identically to those in the linear regulator. The difference is that the output of the error amplifier (the error voltage) is then placed into a voltage-to-pulsewidth converter stage prior to driving the power switches.

There are two major operational types of switching power supplies: the *forward-mode* converter and the *flyback-mode* converter. Although their arrangements of parts are subtly different, their operation is very different and each has advantages in certain areas of application.

3.1.1 The Forward-mode Converter

Forward-mode regulators form a large family of switching power supply topologies. They can be recognized by an L–C filter directly after the power switch or after the output rectifier on the secondary of a transformer. A simple form of the forward-mode regulator can be seen in Figure 3–1. This is called the *buck regulator*.

Its operation can be seen as analogous to a mechanical flywheel and a one-pistoned engine. The L–C filter, like the flywheel, stores energy between the power pulses of the driver. The input to the L–C filter (*choke input filter*) is the chopped input voltage. The L–C filter averages this duty-cycle modulated input voltage waveform. The L–C filtering function can be approximated by

$$V_{out} \approx V_{in}(\text{duty cycle}). \tag{3.1}$$

The output voltage is maintained by the controller by varying the duty cycle. The buck converter is also known as a *step-down converter*, since its output must be less than the input voltage.

The operation of the buck regulator can be seen by breaking its operation into two periods (refer to Figure 3–2). When the switch is turned on, the input voltage is presented to the input of the L–C filter. The inductor current ramps linearly upward and is described as

$$i_{L(on)} = \frac{(V_{in} - V_{out})t_{on}}{L} + i_{init}. \tag{3.2}$$

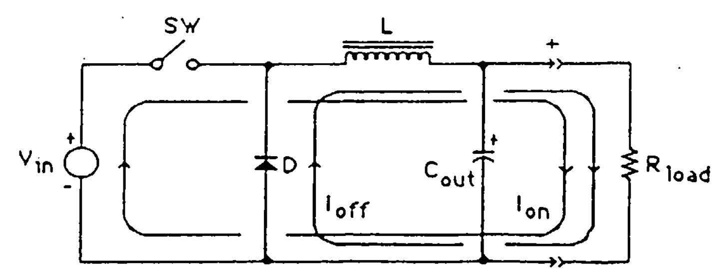


Figure 3–1 A basic forward-mode converter (buck converter shown).

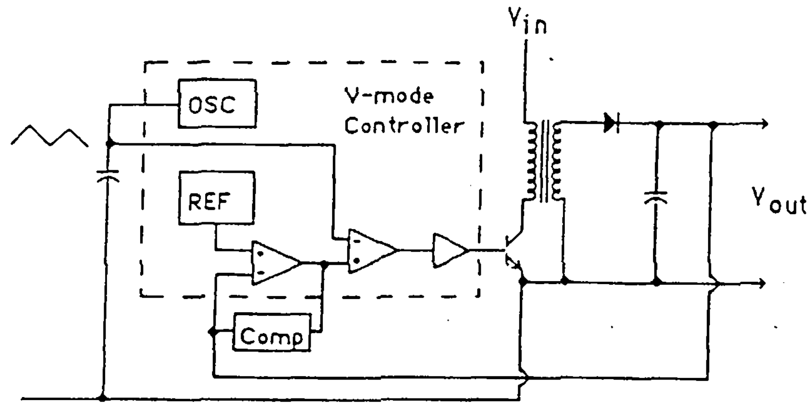


Figure 3–37 Voltage-mode control.

voltage error amplifier that compares the amplifier's output with the ramp voltage across a timing capacitor. Voltage-mode control has two shortcomings: it cannot protect against instantaneous overcurrent conditions in the power switch due to core saturation, and it exhibits a sluggish input transient response. The control ICs also typically have a bipolar-type output driver not readily suitable for power MOSFETs.

Current-mode control includes an ac current feedback loop in addition to the voltage feedback loop. It can be recognized by the output of the error amplifier being input into a comparator that compares the error voltage against the instantaneous power switch current. Now the controller is able to sense an impending core saturation condition or a voltage surge on the input. Hence, a current-mode controlled switching power supply is more robust and can withstand many factors that formerly caused a failure within the supply. The current-mode controller can be seen in Figure 3–38.

The third family of controllers are the variable frequency controllers. These are either *fixed on-time, variable off-time* or *fixed off-time, variable*

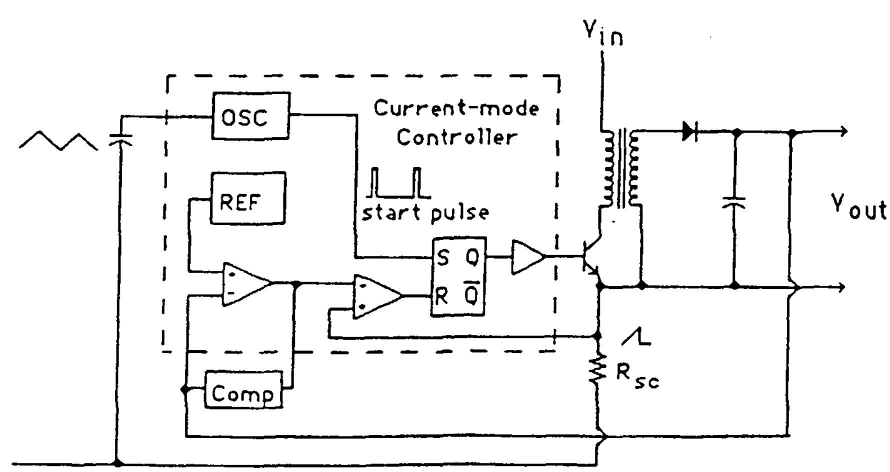


Figure 3–38 A current-mode controller.

on-time. These are typically used for quasi-resonant switching power supplies but can also be used in PWM supplies. Here the error amplifier drives a voltage-controlled oscillator (VCO), which is followed by a one-shot timer. These methods of control are variations on the voltage-mode control and therefore have a poor input transient response characteristic. Three PWM control ICs do use a variable frequency method of control—the uC78S40, the MC34063, and the MC34163. The *gated oscillator* method turns on with fixed pulsewidths that can be overridden by an overcurrent condition and the off-time is used to control the output voltage.

One last factor in the selection of a controller IC is whether it has the power transistor integrated on the same die. The latest developments in power technology are bringing ICs with 0.5–5 A power switches on-board. This eliminates the need for an external power switch and usually saves money. Breakdown voltages of up to 800 V are now available.

Selection of the controller should be based upon the needs of the application. That is, what features would benefit the product and which features render that IC useless? Check carefully items such as low-voltage inhibits on the IC; a 16 V low-voltage inhibit circuit is useless for an application operating from 12 V, and so on. Table 3–7 includes the most popular switching power supply control ICs. For details of their application, refer to the respective manufacturers' data sheets.

3.9 Designing the Voltage Feedback Circuit

The only function of the voltage feedback loop is to hold the output voltage(s) at a constant value. Complications arise in areas such as transient load response, accuracy of the output(s), multiple outputs, and isolated outputs. All of these individually can be nightmares for the designer, but if the design approaches are understood then each factor can be easily addressed.

The heart of the voltage feedback loop is a high-gain operational amplifier called an *error amplifier*, which is nothing more than a high-gain amplifier that enhances the difference between two voltages and creates an error voltage. In power supplies one of these voltages is a reference voltage and the other represents the level of the output voltage. During operation, the output voltage presented to the other input to the error amplifier should be divided down to a voltage identical in value to the reference voltage in order to create a "zero error" output on the error amplifier.

The major design issues surrounding the error amplifier are that it should have a high gain at dc, which promotes good output load regulation, and have a good high-frequency response, which promotes good transient load response. These issues come under the area of feedback loop compensation, which is covered in detail in Appendix B.

An example of an elementary voltage feedback application is the nonisolated, single-output switching power supply. If we neglect the error amplifier compensation, then the design is quite simple. Let us examine a situation where a 5 V output is regulated and a 2.5 V reference is provided within the control IC. This can be seen in Figure 3–39.

To begin the process, one decides how much *sense current* is to be drawn through the output voltage resistor divider. For the sake of reasonable

Appendix C. Power Factor Correction

C.1 Power Factor Correction

Power factor correction is becoming a very important area in the power world. Adding more generating capacity to the world's electrical pool is very costly and would consume additional resources. One method of creating about 30 percent excess generating capacity is to use the ac power more efficiently through the broad use of power factor correction. Motors, electronic power supplies, and fluorescent lighting consume the majority of power in the world and each of these would benefit from power factor correction. In the mid-1990s, many of the countries of the world are going to adopt requirements for power factor correction for the new products marketed within their borders. The added circuitry will add about 20–30 percent to the cost of power supplies, but the near-term energy savings will greatly outweigh the initial costs.

The term "power factor" in the field of power supplies is a slight departure from the traditional usage of the term, which applied to reactive ac loads, such as motors, powered from the ac power line. Here, the current drawn by the motor would be displaced in phase with respect to the voltage. The resulting power being drawn would have a very large reactive component and little power is actually used for producing work.

In switching power supplies, the problem lies in the input rectification and filter network. The typical input circuit and its associated waveforms are shown in Figure C–1. As one can see, the input rectifiers can only conduct current when the ac line voltage exceeds the voltage on the bulk input filter capacitor. This typically occurs within 15 degrees of the crest of the ac voltage waveform. The result is current pulses that are 5–10 times higher than the expected average current draw. This also can lead to distortion of the ac voltage waveform and an imbalance of the three-phase power lines feeding the circuits. This causes a current to flow within the neutral line where no current flow is expected. Another drawback is that no current is drawn when the rectifiers are not conducting, thus throwing away a significant portion of the power system's energy capability.

Power factor correction circuits are intended to increase the conduction angle of the rectifiers and to make the ac input current waveform sinusoidal and in phase with the voltage waveform. The input waveforms can be seen in Figure C–2. This means that all the power drawn from the power line is real power and not reactive. The net result is that the peak and rms current drawn from the line is much lower than that drawn by the capacitive input filter circuit traditionally used.

Active power factor correction (PFC) circuits take the form of non-transformer-isolated switching power supply topologies, such as buck, boost, and buck/boost. The buck topology in Figure C–3 produces an output dc

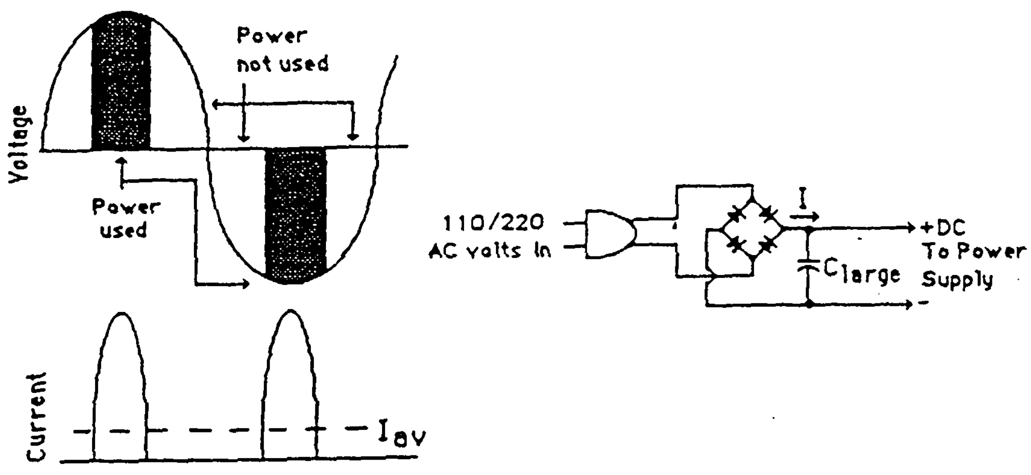


Figure C–1 The waveforms of a capacitive input filter.

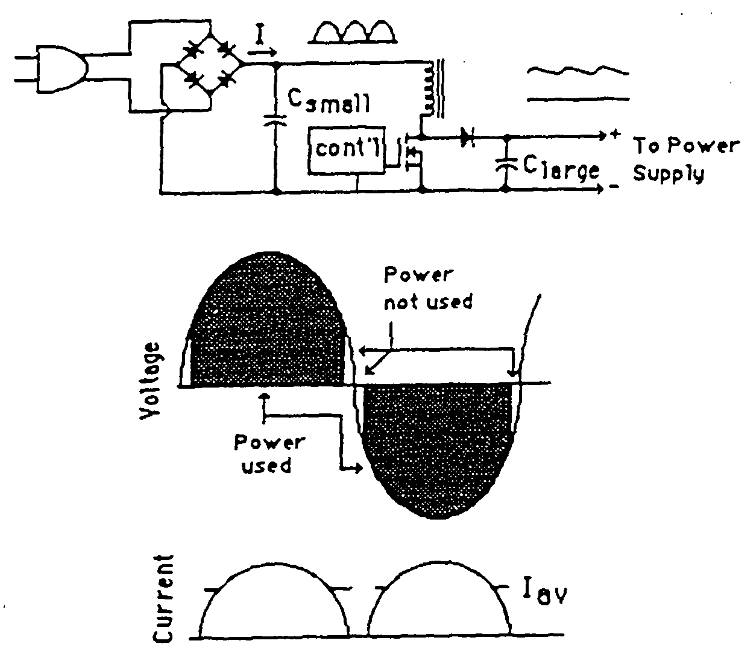


Figure C–2 Power factor corrected input.

voltage lower than found at its input whenever the PFC stage is operating. In other words, the output voltage is typically in the 30–50 VDC range. This can present a problem for higher-powered power supplies, which would then draw a large amount of current from the PFC circuit. The boost and the buck/boost topologies are popular within the field, since they produce a higher dc output voltage than the peak input voltage, which means lower average output currents. These are seen in Figures C–4 and C–5.

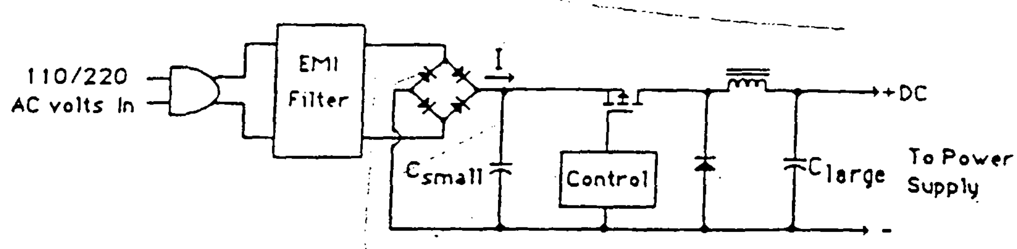


Figure C-3 A buck power factor correction circuit.

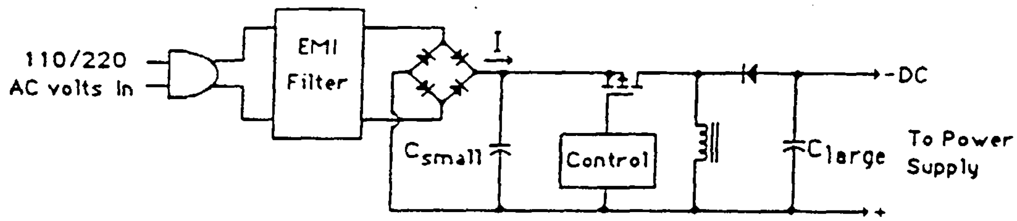


Figure C-4 A buck/boost power factor correction circuit.

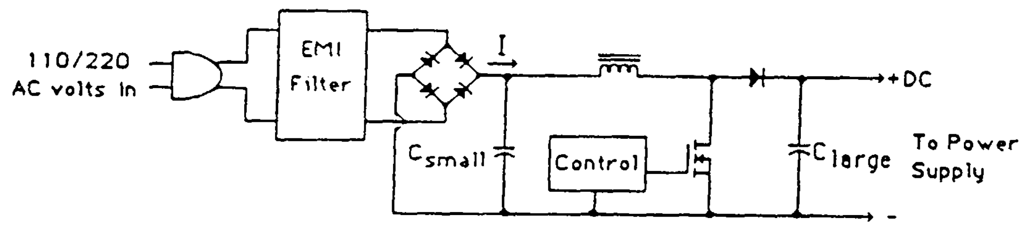


Figure C-5 A boost power factor correction circuit.

The buck/boost develops an output voltage that is negative with respect to the input ground following the rectifiers. The cascaded power supply and the PFC voltage-sense networks must work with a negative voltage, but the dc output voltage can be independent of the values of the rectified input ac waveform. The major disadvantage is the need for a high-side power switch and high breakdown voltage requirements for the semiconductors. The boost topology has become the most popular. It has a low-side power switch that is easy to drive. Its only restriction is that the dc output voltage must be higher than the highest expected ac crest voltage. This means that for a PFC circuit to be useful in all power grids in the world, the output voltage must be greater than 390 VDC, and will pass voltage surges onto the load. Otherwise, it requires the fewest parts and hence costs the least.

Control of the power factor correction stage is a point of debate and battling patents. There are three general methods of control centered around the basic current-mode control philosophy. The basic PFC controller takes the form shown in Figure C–6. There is a multiplier subcircuit inside the control IC that multiplies the instantaneous value of the input full-wave rectified voltage waveform with the output of the error amplifier. This

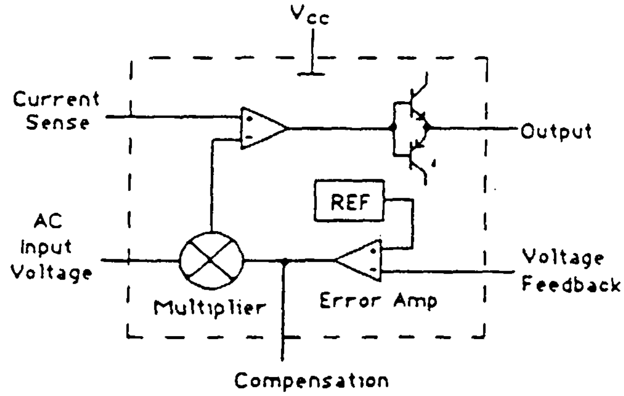


Figure C-6 A generalized typical power factor control IC.

produces a current limit signal that makes the input currents follow a sinusoidal waveshape. The sinusoidal switched current waveform envelope is then filtered by the input EMI filter to produce a 50–60 Hz input current waveform that is free of switching artifacts.

There are three main implementations in the control of PFC circuits: the fixed-frequency average current sensing method as implemented by Unitrode under the Pioneer Magnetics patent (UC3854); the fixed "on" time, peak current sensing method by Microlinear (UL4812); and the critical-conduction, peak current sensing method used by Silicon General (SG3561) and Motorola (MC34261). The latter two methods are variable-frequency methods of control. All the methods produce acceptable power factors as specified by the regulatory agencies at the time of the printing of this book. That situation may change if the requirements become tougher.

The inductor operating mode is a major consideration in designing a PFC circuit. The discontinuous mode of operation is typically used for power levels less than 200 W. It has high peak currents, which limits its use at the higher input power levels. For powers greater than 200 W, the continuous mode of operation is used. This lowers the peak currents seen by the power switch and output rectifier and is much easier to filter in the EMI filter since there are no rapid transitions in the input switched current waveforms. The only disadvantage is that the switching losses rise significantly because the power switch must force off the output rectifier at the beginning of each "on" time period. The choice of output rectifier (low T_{rr}) becomes critical to the operation of the PFC stage. Some gallium arsenide rectifiers under development may reduce this problem.

C.1.1 How the Power Factor is Specified

I strongly recommend engaging a third-party EMI testing house to test your company's products. The minimum level of test equipment required to test for the factors discussed is very expensive and there is a learning period involved.

The following discussion is based upon IEC555 prerelease drafts. The limits presented in this specification may change prior to its release. Also the United States and Canada are developing specifications of their own that

will probably follow the guidelines presented by IEC555 but may contain additional requirements. This is a developing field, so be aware of the most recent specifications at the time of your product release.

The real power delivered to a load is given by

$$P_{in} = V_{in} I_{in} \cos \phi \qquad \text{(C.1)}$$

where

$$\phi = \text{Power Factor} = \frac{\text{Real power}}{\text{Real power} + \text{Reactive power}}. \qquad \text{(C.2)}$$

In terms of strictly reactive passive loads, the power factor is the resulting phase between the voltage and the current waveforms. In power supplies though, it is the time during which the current is flowing that is related to the conduction angle of the input rectifiers. Power factor is measured from 0 to 1 where 1 means that all the power is used by the load. The typical capacitive input filter found in power supplies has an average power factor of 0.5–0.7.

In running the tests, a power analyzer must be used such as the Voltech PM1000, PM1200, or PM3000. An audio spectrum analyzer is also needed to measure the amplitude of the harmonic components of the ac current. The total input voltage and currents are given by

$$V_{rms(total)} = \sqrt{V^2_{fund(rms)} + V^2_{1(rms)} + V^2_{2(rms)} \cdots} \qquad \text{(C.3)}$$

and

$$I_{rms(total)} = \sqrt{I^2_{fund(rms)} + I^2_{1(rms)} + I^2_{2(rms)} \cdots} \qquad \text{(C.4)}$$

where the subscripts 1, 2, . . . indicate the harmonics. In power supplies the third harmonic is by far the largest and therefore the largest problem. Harmonics cause problems because, in a pure sense, only the fundamental current frequency produces real power, so that the reduction of harmonics produces a better power factor.

A term used in PFC is *total harmonic distortion*. This is defined as

$$\text{THD} = \frac{I_{1(rms)} + I_{2(rms)} \cdots}{I_{rms(total)}} \qquad \text{(C.5)}$$

and it is an indication of the performance of a PFC circuit.

From the power analyzer or the spectrum analyzer, one can measure the amplitude values needed to verify compliance with the PFC specifications. At the time of publishing, only IEC555-2 had been made public and its limits are given in Table C-1. These limits must be measured with an LISN (line impedance stabilization network) as specified by the regulatory agencies. This makes the input power line a 50 Ω impedance and serves the basis of all of these tests. The test results are highly dependent upon the ac line impedance.

Some comments on the design of PFC circuits. First, the EMI filter is an integral part of any PFC circuit. It filters out the switching noise from the input current waveform. Without an EMI filter, your product will fail the EMI/RFI tests which are in addition to the power factor tests. Refer to Appendix E for the design of an EMI filter. Secondly, using a variac during the measurements will affect the input line impedance and thus affect the validity of the data you are trying to measure. Variacs usually make the data

Table C-1 IEC555-2 (1989) Harmonic Current Limits (Class A)

Harmonic	Absolute Limits (Amps RMS)
2	1.08
3	2.30
4	0.43
5	1.14
7	0.77
9	0.44
$15 < n < 39$	$0.15(15/n)$

better than it really is. Thirdly, all voltage measurements must be differential and use the specified current-measuring apparatus.

C.2 A Universal Input, 180 W, Active Power Factor Correction Circuit

This design example demonstrates the design process of a 180 W discontinuous-mode boost PFC circuit. It can be scaled to provide output powers up to 200 W. The PFC stage is designed to work from every residential ac power system in the world, that is, from 85 to 270 VRMS at 50 and 60 Hz without the need for a jumper.

Design specification

AC input voltage range:	85–270 VRMS
AC line frequencies:	50–60 Hz
Output voltage:	400 VDC ± 10 V
Input power factor at rated load:	>98 percent
Total harmonic distortion (THD):	Under IEC555-2 limits

Predesign considerations

Having a rating less than 200 W has many benefits for a power factor correction stage. The major benefit is that it can operate in the discontinuous mode. In higher-power PFC designs the continuous mode must be employed, which presents a significant loss within the circuit due to the reverse recovery time of the output rectifier. In fixed-frequency discontinuous-mode PFC controllers there is still a period when the circuit operates in the continuous mode ($V_{in} <$ approx. 50 V). By employing a *critical conduction-mode* controller, the designer can guarantee that the continuous mode is never entered.

The first consideration is to determine the peak ac input voltages.

110 V input:

$$V_{in(nom)} = 1.414(110\text{ V}) = 155.5\text{ V}.$$
$$V_{in(hi)} = 1.414(130\text{ V}) = 183.8\text{ V}.$$

240 V input (Britain—worst case):

$$V_{in(nom)} = 1.414(240\text{ V}) = 339.4\text{ V}.$$
$$V_{in(hi)} = 1.414(270\text{ V}) = 381.8\text{ V}.$$

The output voltage should be higher than the highest anticipated input peak crest voltage. The output voltage of the PFC stage is chosen to be 400 VDC.

The maximum value for the peak inductor current will occur at the crest voltage of the minimum expected ac input voltage. This is

$$
\begin{aligned}
I_{pk(max)} &= 1.414(2)(P_{out(rated)})/(\mathrm{eff}_{est})(V_{in(min)rms}) \\
&= 1.414(2)(180\ \mathrm{W})/(0.9)(85\ \mathrm{V_{rms}}) \\
&= 6.6\ \mathrm{A}.
\end{aligned}
$$

Inductor design

In designing the boost inductor, one would designate the point of reference as the crest voltage of the minimum expected ac input voltage. For any set of operating conditions with this method of PFC control, i.e., fixed load and ac input voltage, the "on" time pulsewidth remains constant over the entire half-sinusoid waveform. To determine the "on" time at the minimum peak ac input voltage one evaluates the following:

$$
R = \frac{V_{out(dc)}}{\sqrt{2}V_{in\text{-}ac(min)}} = \frac{400\ \mathrm{V}}{1.414(85\ \mathrm{V_{rms}})}.
$$

$$
R = 3.3.
$$

The maximum "on" time that occurs at this point is

$$
\begin{aligned}
T_{on(max)} &= \frac{R}{f(1+R)} = \frac{3.3}{(50\ \mathrm{kHz})(1+3.3)} \\
&= 15.3\ \mu\mathrm{s}.
\end{aligned}
$$

The approximate maximum value of the boost inductor is

$$
\begin{aligned}
L &\approx \frac{T_{on(max)}(\sqrt{2}V_{in\text{-}ac(min)})^2(\mathrm{eff})}{2P_{out(max)}} \\
&\approx \frac{(15.3\ \mu\mathrm{s})(1.414(85\ \mathrm{V_{rms}})(0.9)}{2(180\ \mathrm{W})} \approx 552\ \mu\mathrm{H}.
\end{aligned}
$$

The power winding of the inductor (transformer) must support not only the maximum average input current but the output current as well. The wire gauge of the winding should be

$$
\begin{aligned}
I_{W(max\text{-}av)} &= \frac{P_{out}}{\mathrm{eff}(V_{in(rms)})} + \frac{P_{out}}{V_{out}} \\
&= \frac{180\ \mathrm{W}}{(0.9)(85\ \mathrm{V_{rms}})} + \frac{180\ \mathrm{W}}{400\ \mathrm{V}} = 2.8\ \mathrm{A}.
\end{aligned}
$$

The wire gauge to accommodate this average current would be #17 AWG. I will use three strands of #20 AWG (which adds up to the same wire cross-sectional area), which is more flexible during the winding process and will help reduce the ac resistance of the winding due to the skin effect. Also, owing to the high voltages present within the same winding, I will be using quad-thickness insulation to reduce the threat of interturn arc-overs.

I am selecting a PQ core style. A major concern is the length of air-gap required for various core styles in unipolar applications. The larger air-gaps (>50 mils) cause excessive electromagnetic radiation into the immediate

environment, thus making it harder to filter RFI. To reduce the air-gap, one needs to find a ferrite core with the largest core cross-sectional area for a given core size. The PQ core has this characteristic. Referring to the W_aA_c vs. power charts provided by Magnetics, Inc., the resulting PQ core part number is P-43220-XX. (XX is the gap length in mils.)

The approximate air-gap needed in the core is

$$l_{gap} \approx \frac{0.4\pi L I_{pk} \times 10^8}{A_c B_{max}^2}$$

$$\approx \frac{0.4\pi(552\,\mu\text{H})(6.6\,\text{A}) \times 10^8}{(1.70\,\text{cm}^2)(2000\,\text{G})^2} \approx 66\,\text{mils}.$$

Let us make the air-gap 50 mils, which is a custom air-gap. Magnetics has no problem with this practice and usually adds only a couple of percent to the core cost. The inductance factor (A_L) for this core with this gap is estimated at 160 mH/1000 turns (using a linear extrapolation of A_L reduction vs. air-gap length).

The number of turns needed for this inductance is

$$N = 1000\sqrt{\frac{0.55\,\text{mH}}{160\,\text{mH}}} = 59\ \text{turns}.$$

Checking to see whether the core will support this many turns (neglecting the auxiliary winding area):

$$\frac{A_W}{W_A} = \frac{(59)(0.471\,\text{mm}^2)}{47\,\text{mm}^2} = 59\%\text{—OK}.$$

Designing the auxiliary winding. The auxiliary winding will have the low-frequency (100–120 Hz) variation on its output peak rectified voltage, so the controller filter capacitor needs to be large to minimize the droop in the V_{cc} of the controller. The highest flyback-mode rectified voltage will occur at low input voltages and will be of the form

$$V_{aux} \approx \frac{N_{aux}(V_{out} - V_{in})}{N_{pri}}.$$

This ac waveform is seen in Figure C–7.

The MC34262 has a high-side driver clamp of 16 VDC, so in order to keep the high-side driver dissipation to a minimum, the peak voltage of the rectified auxiliary voltage should be around 16 V. Determine the turns ratio needed for this from

$$N_{aux} = \frac{(59)(16\,\text{V})}{(400\,\text{V} - 30\,\text{V})} = 2.5\ \text{turns}.$$

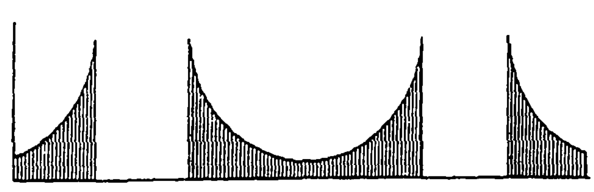


Figure C–7 The rectified ac waveform present on the auxillary winding.

I will make this winding three turns because of concern about low ac line operation. I will use one strand of #28 AWG heavy insulated magnet wire.

The capacitor needed to filter this voltage with approximately 2 V of voltage ripple is

$$C_{aux} \approx \frac{I_{dd} T_{off}}{V_{ripple}} = \frac{(25\text{ mA})(6\text{ ms})}{2.0\text{ V}}$$
$$= 75\,\mu\text{F—make } 100\,\mu\text{F @ } 20\text{ VDC.}$$

Transformer construction

The two-winding transformer will be constructed by first winding the 59 turns of the three strands of #20 AWG quad-thickness magnet wire onto the bobbin. Then place two layers of Mylar tape. Then the three turns for the auxiliary winding, and lastly three layers of Mylar tape. The internal layers of tape are to discourage any arcing that may occur due to the high voltages between the primary winding and the auxiliary winding. See Figure C–8.

Designing the start-up circuit

I will use a passive resistor for starting up the control IC and to provide current to the gate drive of the MOSFET. For the resistor I need to use two resistors placed in series, since the 370 V peak on the rectified input is comparable to the breakdown voltage of the resistors themselves. The start-up resistors will charge the 100 μF bypass capacitor and the subsequent energy stored in the capacitor must be sufficient to operate the control IC for the 6 ms before the worst-case rectified peak voltage from the auxiliary winding is available to operate the IC. The start-up voltage threshold hysteresis is 1.75 V minimum. Check whether the bypass capacitor is large enough to start the circuit before the turn-off threshold is reached:

$$V_{drop} = \frac{I_{dd} T_{off}}{C} = \frac{(25\text{ mA})(6\text{ ms})}{100\,\mu\text{F}}$$
$$= 1.5\text{ V—OK.}$$

I would like to keep the dissipation less than 1 W at the high input voltage line. To do this one needs to determine the maximum current that should pass through the start-up resistors.

$$I_{start} < \frac{1.0\text{ W}}{270\text{ V}_{rms}} = 3.7\text{ mA.}$$

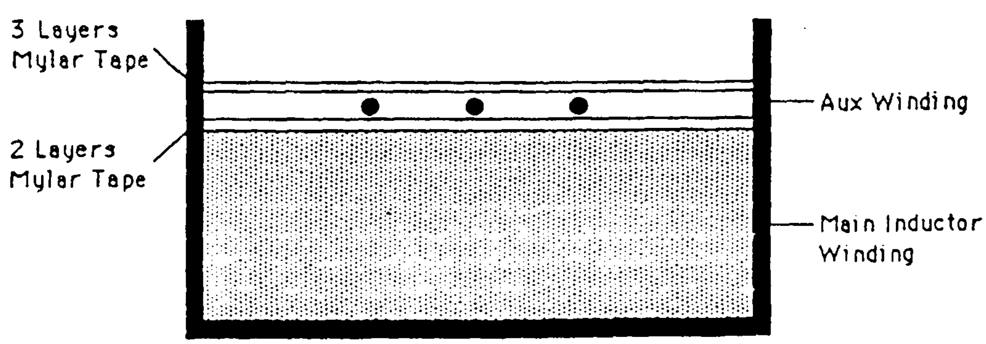


Figure C–8 Construction of the PFC boost inductor.

The total resistance is then

$$R_{start} = \frac{270\text{ V} - 16\text{ V}}{3.7\text{ mA}} = 68\text{ k}\Omega\text{ (min)}.$$

Make the total resistance about 100 kΩ or two 47 kΩ, $\frac{1}{2}$ W resistors.

Designing the voltage multiplier input circuit

The maximum specified limit of the input to the multiplier (pin 3) is 2.5 V. This level should be the peak value of the divided rectified input waveform at the highest expected ac input voltage at the crest of the sinusoid (370 V). If a sense current of 200 μA is selected at this point, the resistor divider becomes

$$R_{bottom} = \frac{2.5\text{ V}}{200\ \mu\text{A}} = 12.5\text{ k}\Omega\text{—make }12\text{ k}\Omega.$$

The true sense current is 2.5 V/12 K = 208 μA.

The top resistor becomes

$$R_{top} = \frac{370\text{ V} - 2.5\text{ V}}{208\ \mu\text{A}} = 1.76\text{ M}\Omega.$$

Make this two resistors in series each with a value of 910 kΩ.

The power ratings of these resistors are $P = (370\text{ V})^2/1.76\text{ M}\Omega$ or 0.8 W. Each resistor should have $\frac{1}{2}$ W power rating.

Design of the current sensing circuit

The current sense resistor should be sized in order to reach the 1.1 V current sense threshold voltage at the low ac input voltage. The value then becomes

$$R_{cs} = \frac{1.1\text{ V}}{6.6\text{ A}} = 0.33\ \Omega.$$

A leading edge spike filter of 1 kΩ and 470 pF will also be added before inputting the current signal to pin 4.

Designing the voltage feedback circuit

For the output voltage sense resistor divider, selecting the sense current as 200 μA, the lower resistor becomes

$$R_{bottom} = \frac{V_{ref}}{I_{sense}} = \frac{2.5\text{ V}}{200\ \mu\text{A}} = 12.5\text{ k}\Omega\text{—make }12.0\text{ k}\Omega.$$

This makes the true sense current 2.5 V/12 K = 208 μA.

The upper resistor is

$$R_{upper} = \frac{(400\text{ V} - 2.5\text{ V})}{208\ \mu\text{A}} = 1.91\text{ M}\Omega.$$

Make this resistor a 1 MΩ and a 910 kΩ resistor in series, each with a $\frac{1}{2}$ W rating.

The compensation of the voltage error amplifier should be a single-pole rolloff with a unity gain frequency of 38 Hz. This is required to reject the

fundamental line frequencies of 50 and 60 Hz. The feedback capacitor around the voltage error amplifier becomes

$$C_{fb} = \frac{1}{2\pi f R_{upper}} = \frac{1}{2\pi(38\text{ Hz})(1.82\text{ M}\Omega)}$$
$$= 0.043\ \mu\text{F, or } 0.05\ \mu\text{F}.$$

Designing the input EMI filter section

I will use a second-order, common-mode filter. The difficulty in considering an input-conducted EMI for this power factor correction circuit is its variable frequency of operation. The lowest instantaneous frequency of operation occurs at the crests of the sinusoid voltage waveform. This is where the core requires the longest time to completely discharge the core. The estimated frequency of operation was 50 kHz, so I will use this as an assumed minimum frequency.

A good starting point is to assume that I will need 24 dB of attenuation at 50 kHz. This makes the corner frequency of the common-mode filter

$$f_c = f_{sw} \times 10^{(\text{Att}/40)}$$

where Att is the attenuation needed at the switching frequency in negative dB.

$$f_c = (50\text{ kHz})\,10^{(-24/40)} = 12.5\text{ kHz}.$$

Assume that a damping factor of 0.707 or greater is good and provides a −3 dB attenuation at the corner frequency, and does not produce noise due to ringing. Also assume that the input line impedance is 50 Ω since the regulatory agencies use an LISN test that makes the line impedance equal this value. Calculating the values needed in the common-mode inductor and "Y" capacitors:

$$L = \frac{R_L \zeta}{\pi f_c} = \frac{(50\,\Omega)(0.707)}{\pi(12.5\text{ kHz})} = 900\ \mu\text{H}.$$

$$C = \frac{1}{(2\pi f_c)^2 L} = \frac{1}{[2\pi(12.5\text{ kHz})]^2(900\ \mu\text{H})} = 0.18\ \mu\text{F}.$$

Real-world considerations do not allow a capacitor of this large a value. The largest value capacitor that will pass the ac leakage current test is 0.05 μF. This is 27 percent of the calculated capacitor value, so the inductor must be increased to 360 percent of its former value in order to maintain the same corner frequency. The inductance then becomes 3.24 mH and the resultant damping factor is 2.5, which is acceptable.

Coilcraft offers off-the-shelf common-mode filter chokes (transformers) and the part number closest to this value is E3493. With this filter design I can expect a minimum of −40 dB between the frequencies of 500 kHz and 10 MHz. If later during the EMI testing stage I find I need additional filtering, I will add a third order to the filter design by using a differential-mode filter.

The schematic of the resulting power factor correction circuit is given in Figure C–9.

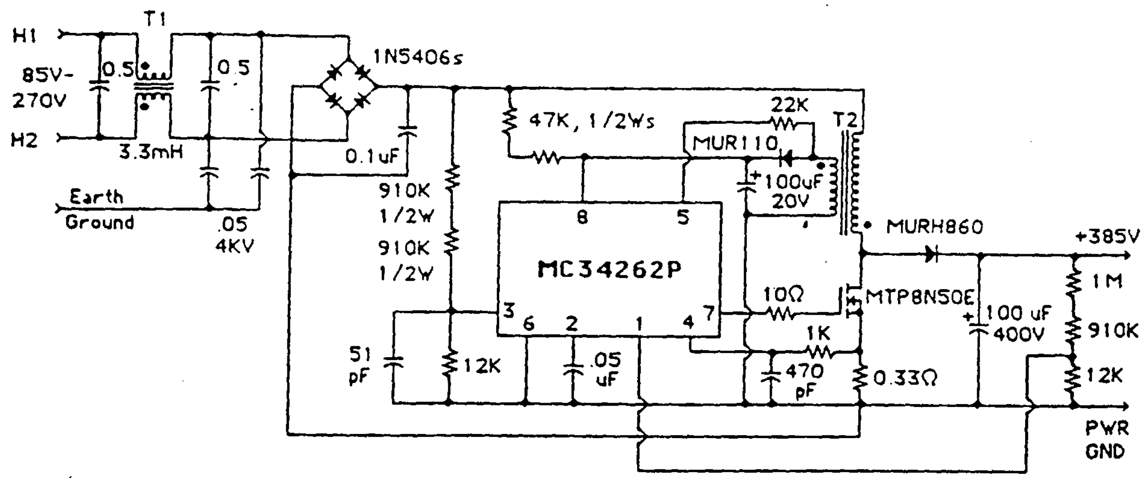


Figure C-9 The schematic for the 180 W power factor circuit (with EMI filter).

C.2.1 Printed Circuit Board Considerations

The unit in which this power factor correction circuit resides is going to be marketed everywhere in the world. The toughest safety requirements are issued by VDE in Germany. Here the *creepage* distance, or the distance that an arc must travel over a surface, is 4.0 mm for those signals that are opposite phases of an ac power line up to 300 V_{rms}. This means that there must be 4.0 mm spacing between traces of H1 and H2 (Hot and Neutral), and their rectified dc signals. Also there must be a 4.0 mm (minimum) surface distance between the windings on the input common-mode filter transformer and between high and low pins of the flyback inductor. The spacing of the 400 V output must be more than 4.0 mm from all other traces carrying less voltage. The creepage between any earth ground trace and the other traces must be more than 8.0 mm.

All current-carrying traces should be as wide and as short as possible. One-point grounding practices between the input, output, and low-level grounds should be done at the ground side of the current sense resistor.

magnetic material should be used in the enclosure construction. The material should be iron, steel, nickel, or Mu metal. For plastic enclosures, there are an assortment of conductive paints that can be used to add EMI/RFI shielding to the case. Also, any vent openings may need magnetic screening covering the openings.

The philosophy of any EMI shield is to encourage eddy currents to flow within the surfaces, thus dissipating the noise energy. Also, the overall enclosure should act as a gaussian enclosure where there is good electrical conduction totally around the enclosure. Thus removable hatches and enclosure members need very good electrical conduction around their peripheries. RF gasketing is sometimes used in particularly troublesome cases.

Leads that enter or exit the enclosure should ideally have their associated EMI filters at the point of entry or exit from the enclosure. Any unfiltered leadlengths that run within the enclosure will pick up noise inductively within the case and allow it to exit the case, thus making any EMI filtering less effective. Likewise, any unfiltered leads within the case will radiate any transients from outside the case into the case. This can adversely affect the static discharge susceptibility of the entire product.

E.4 Conducted EMI Filters

There are two types of input power buses: dc power buses, which are single-wire feeds such as found in automobiles and aircraft; and ac, two-, or three-wire feed systems such as found in ac power systems. The design of the EMI filter for dc systems is covered in Section 3.12 and takes the form of a simple L–C filter. All the noise is common-mode between the single power wire and the ground return. The ac filter is much more complicated to design because of the parasitic behavior of the components involved. All noise testing requires very expensive test equipment and is best done by a third-party EMI/RFI testing company.

To design a filter for the input of a switching power supply, the designer first needs to know which of the regulatory specifications is appropriate for

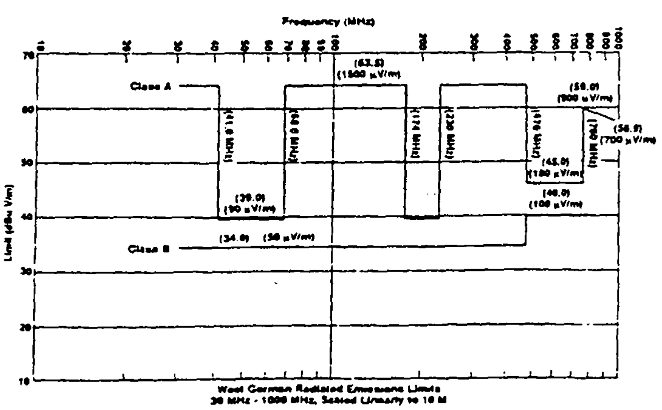


Figure E–4 VDE limits on radiated EMI.

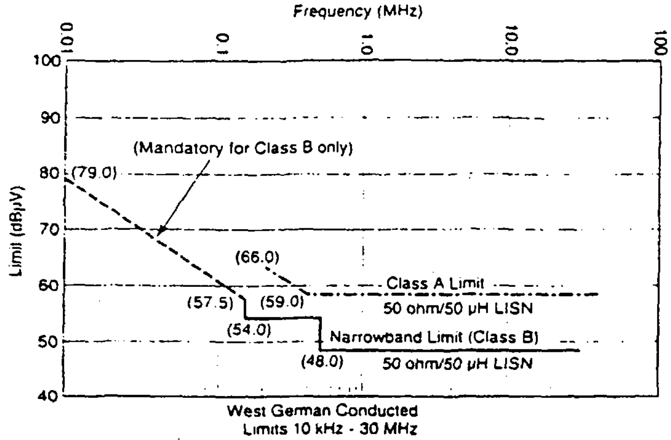


Figure E–5 VDE limits on conducted EMI.

the product. The specifications dictate the conducted and radiated limits that the entire product must meet in order to be sold into the market of interest. The marketing department should know which requirements are appropriate for the target market. It is always a good idea to design for the most stringent specification that is applicable to your market. For products to be sold in the European market, VDE has the most stringent limits. The VDE radiated limits are shown in Figure E–4, and the conducted limits are shown in Figure E–5. Class A limits are for equipment marketed in industrial environments and Class B are for residential markets.

The purpose of an input conducted EMI filter is to keep the high-frequency noise inside the case, so the appropriate noise source is mainly the switching power supply. Filtering on any of the input/output (I/O) lines is to keep noise from any internal circuit, like microprocessors, inside the case.

E.4.1 Design of the Common-mode Filter

The common-mode filter essentially filters out noise that is generated between the two power lines (Hot and Neutral or H1 and H2). The common-mode filter schematic is shown as part of Figure E–6.

In the common-mode filter the windings of the "transformer" are out of phase. The result is that the flux within the core cancels for those signals that are equal and opposite on the two power lines. However, any noise that is different between the two power lines is coupled through the core and "shorted out," thus not being allowed to pass through the filter.

The problem in designing the common-mode filter is that at high frequencies, where one wants and needs the filtering, the ideal characteristics of the components are compromised by their parasitic characteristics. The major parasitic is the *interturn capacitance* of the transformer itself. This is the small level of capacitance that exists in all windings, in which the voltage difference (volts/turn) between turns behaves like a capacitor. This capacitor, at high frequency, effectively acts as a shunt around the winding and allows more high-frequency ac current to go around the windings. The frequency at which this becomes a problem is above what is called the *self-resonance* of the winding. A tank circuit is formed between the winding

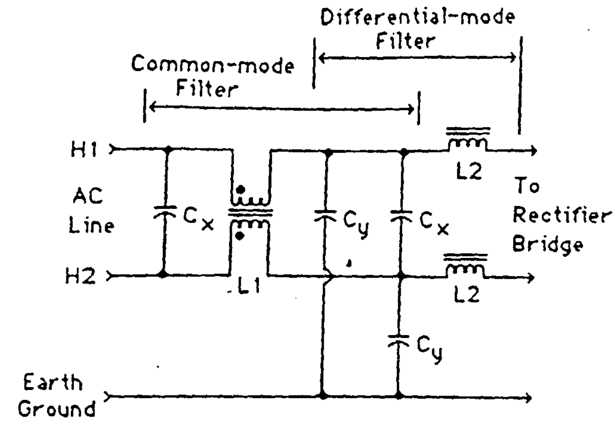


Figure E-6 A complete third-order, input EMI filter (common-mode and differential-mode)

inductance itself and this distributed interturn capacitance. Above the self-resonance point the capacitance becomes larger in value than the inductance, which then reduces the level of attenuation at high frequencies The effect of this within the common-mode filter can be seen in Figure E–7. Its effect can be reduced by purposely using a larger X capacitor. The self-resonance frequency is the point in Figure E–7 at which the greatest possible attenuation for the filter is exhibited. By choosing the winding method of the transformer, one can locate this point on top of a frequency that needs the greatest filtering, such as a harmonic peak in the unfiltered system noise curve.

Another area of concern is the Q of the filter at self-resonance. If the Q is too high—in other words, if the damping factor is too low—the filter will actually generate noise in the form of narrow-band ringing. This can be dealt with during the design.

Some major transformer manufacturers build standard off-the-shelf components used in the design of common-mode filter transformers, such as Coilcraft. These transformers have various inductance values and current ratings, and also provide the needed creepage dimensions. This can make the designer's job a lot easier.

The initial common-mode filter component values can be determined in a step-by-step process (like everything else in this book). To begin this process, either a baseline measurement of the unfiltered conducted noise spectrum is needed, or some assumptions need to be made, in order to determine how much attenuation is needed and at what frequencies. Obviously, making the measurement will yield a good result (with minor tweaks) the first time. Assuming on paper that one needs a particular filter response may lead to additional "fudging" of the circuit on the test table.

A reasonable beginning is to assume that one needs about 24 dB of attenuation at the switching frequency of the switching power supply. This, of course, should be modified in response to the actual conducted noise spectral shape. One determines the corner frequency of the 2 pole filter from

$$\text{Attenuation}(-\text{dB}) = 40 \log\left(\frac{f_c}{f_{sw}}\right)$$

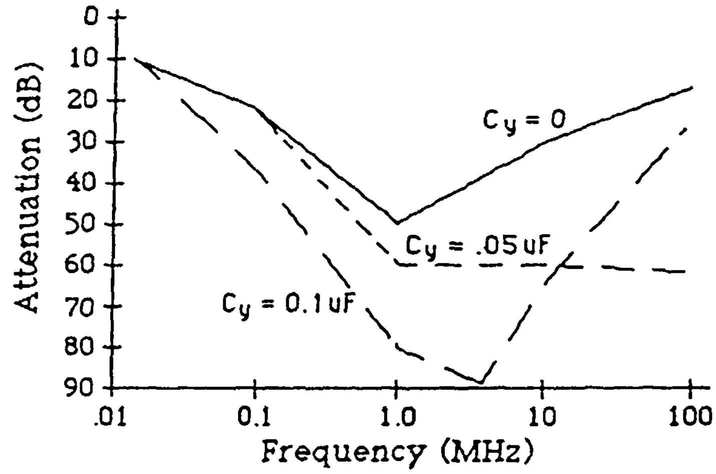


Figure E-7 *Frequency response of a second-order common-mode filter (L = 1 mH).*

or

$$f_c = f_{sw} \times 10^{(Att/40)}$$

where f_c is the desired corner frequency of the filter
f_{sw} is the operating frequency of the power supply

For this example, the switching frequency is assumed to be 50 kHz. The corner frequency to produce −24 dB of attenuation at this point is

$$f_c = (50\,\text{kHz}) \times 10^{(-24/40)} = 12.5\,\text{kHz}.$$

One assumes that the line impedance is 50 Ω (because that is the LISN test impedance). This impedance is then the damping element within the reactive filter circuit.

Choosing the damping factor

The minimum damping factor (ζ) should be no less than 0.707. Less than that would allow ringing to occur and produce less than 3 dB of attenuation at the corner frequency.

Calculating the initial component values

$$L = \frac{R_L \zeta}{\pi f_c} = \frac{(50\,\Omega)(0.707)}{\pi(12.5\,\text{kHz})} = 900\,\mu\text{H}.$$

$$C = \frac{1}{(2\pi f_c)^2 L} = \frac{1}{[2\pi(12.5\,\text{kHz})]^2(900\,\mu\text{H})} = 0.18\,\mu\text{F}.$$

Choosing "real-world" available components

The largest value of capacitor that is available in the 4 kV voltage rating is 0.05 μF. This is 27 percent of the calculated value. In order for the corner frequency to remain the same, the inductor value should be increased by a factor of 3.6. This would make the value 3.24 mH. The damping factor is directly proportional to the value of the inductance, so the resultant damping factor is 2.5, which is acceptable.

The closest Coilcraft common-mode inductor part number is E3493 and its self-resonance frequency is 1 MHz. The calculated capacitors are what are typically called "Y" capacitors. These are placed between each phase and the earth ground and must meet the full HIPOT test voltage of 2500 V_{rms}. "X" capacitors are placed between the power lines and need only meet the 250 V_{rms} rating of the power line and be able to withstand any surge that may be anticipated. Choosing the value of the X capacitors is mainly arbitrary and they usually fall in the 0.001–0.5 mF range.

One can reasonably expect this filter to provide a minimum of 60 dB of attenuation between the frequencies of 500 kHz and 10 MHz.

Once the component values have been calculated, the physical construction of the transformer and the PCB layout become critical for the effectiveness of the filter stage. Magnetic coupling due to stray inductive pick-up of high-frequency noise by the traces and components can circumvent the filter altogether; added to this is the fact that the common-mode filter choke looks more and more capacitive above its self-resonance frequency. The net result is that the designer needs to be concerned about the high frequency behavior of the filter typically above 20–40 MHz.

Physical layout of the PCB is important. The filter should be laid out in a linear fashion so that the input portion of the filter is physically distant from the output portion. Large, low-inductance traces should also be used, but keeping in mind the creepage requirements of the regulatory specifications.

Sometimes the high-frequency attenuation is insufficient to meet the specifications and a third pole has to be added to the EMI filter. This filter is typically a differential-mode filter and will share the Y capacitors from the common-mode filter. Its corner frequency is typically the same as that of the common-mode filter. This filter is made up of a separate choke on each power line, and is placed between the input rectifiers and the common-mode filter.

The differential-mode filter should have a lower damping factor than the common-mode filter because the combined damping response of the entire filter section would be too sluggish if higher damping factors were used. A minimum damping factor of 0.5 is acceptable.

Calculating the differential-mode choke value

$$L_d = \frac{R_L \zeta}{2\pi f_c} = \frac{(50\,\Omega)(0.5)}{2\pi(12.5\text{ kHz})} = 318\,\mu\text{H}.$$

The addition of this stage of filtering will bring the very high frequency attenuation under control and further attenuate any differential-mode noise on the earth ground lead. It will also produce a combined attenuation of −36 dB at the switching frequency of the power supply.

Real-world considerations

If one builds the inductive elements instead of buying off-the-shelf parts from a manufacturer, the following guidelines are common industry practices.

Common-mode chokes (transformers)

1. A toroid is best for this application because it produces very few stray magnetic fields.

2. A high permeability ferrite is used such as the W material from Magnetics, Inc. which has a permeability of 10 000.
3. If an E–E core is used (a common choice), there should be no air-gap and the mating surfaces of the cores must be polished. Any surface imperfections would lower the permeability.
4. The bobbin should be a two-section bobbin and should not be completely filled with windings. A 2 mm space from the outside surface of the bobbin is required for the 4 mm creepage requirement of VDE.

Differential-mode chokes

1. These are wound on separate cores (not mutually coupled).
2. Use a powdered iron material such as available from MicroMetals.
3. Bar cores are typically used because of cost.

MOTOROLA

MC34261
MC33261

Power Factor Controllers

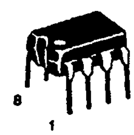
The MC34261/MC33261 are active power factor controllers specifically designed for use as a preconverter in electronic ballast and in off–line power converter applications. These integrated circuits feature an internal startup timer, a one quadrant multiplier for near unity power factor, zero current detector to ensure critical conduction operation, high gain error amplifier, trimmed internal bandgap reference, current sensing comparator, and a totem pole output ideally suited for driving a power MOSFET.

Also included are protective features consisting of input undervoltage lockout with hysteresis, cycle–by–cycle current limiting, and a latch for single pulse metering. These devices are available in dual–in–line and surface mount plastic packages.

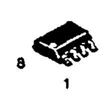
- Internal Startup Timer
- One Quadrant Multiplier
- Zero Current Detector
- Trimmed 2% Internal Bandgap Reference
- Totem Pole Output
- Undervoltage Lockout with Hysteresis
- Low Startup and Operating Current
- Pinout Equivalent to the SG3561
- Functional Equivalent to the TDA4817

POWER FACTOR CONTROLLERS

SEMICONDUCTOR TECHNICAL DATA

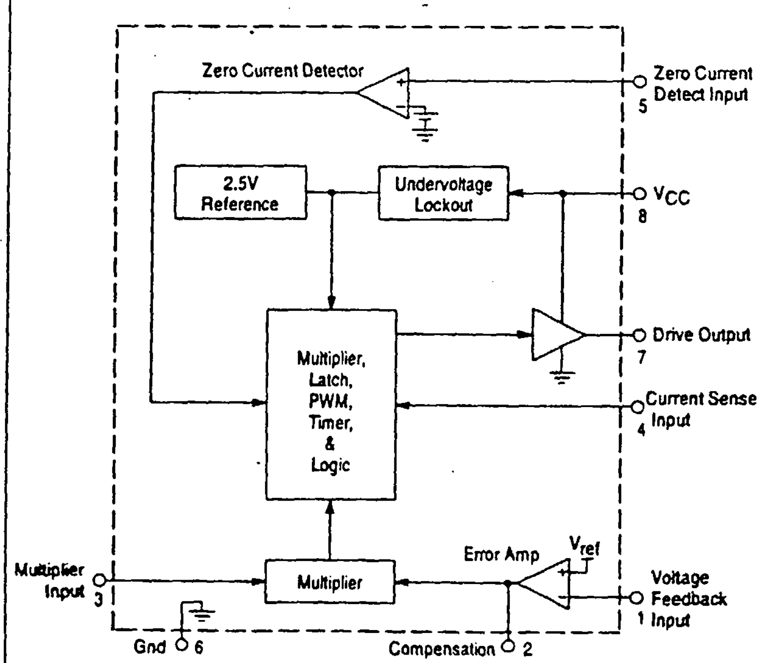


P SUFFIX
PLASTIC PACKAGE
CASE 626

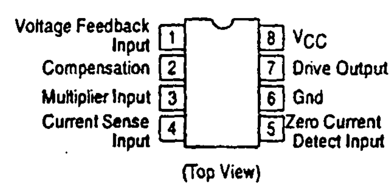


D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)

Simplified Block Diagram



PIN CONNECTIONS



ORDERING INFORMATION

Device	Operating Temperature Range	Package
MC34261D	T_A = 0° to +70°C	SO–8
MC34261P		Plastic DIP
MC33261D	T_A = –40° to +85°C	SO–8
MC33261P		Plastic DIP

Rev 1

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Total Power Supply and Zener Current	$(I_{CC} + I_Z)$	30	mA
Output Current, Source or Sink (Note 1)	I_O	500	mA
Current Sense, Multiplier, and Voltage Feedback Inputs	V_{in}	−1.0 to 10	V
Zero Current Detect Input High State Forward Current Low State Reverse Current	I_{in}	 50 −10	mA
Power Dissipation and Thermal Characteristics P Suffix, Plastic Package Case 626 Maximum Power Dissipation @ T_A = 70°C Thermal Resistance, Junction–to–Air D Suffix, Plastic Package Case 626 Maximum Power Dissipation @ T_A = 70°C Thermal Resistance, Junction–to–Air	 P_D $R_{\theta JA}$ P_D $R_{\theta JA}$	 800 100 450 178	 mW °C/W mW °C/W
Operating Junction Temperature	T_J	+150	°C
Operating Ambient Temperature (Note 3) MC34261 MC33261	T_A	 0 to +70 −40 to +85	°C
Storage Temperature	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (V_{CC} = 12 V, for typical values T_A = 25°C, for min/max values T_A is the operating ambient temperature range that applies [Note 3], unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
ERROR AMPLIFIER					
Voltage Feedback Input Threshold T_A = 25°C T_A = T_{low} to T_{high} (V_{CC} = 12 V to 28 V)	V_{FB}	 2.465 2.44	 2.5 	 2.535 2.54	V
Line Regulation (V_{CC} = 12 V to 28 V, T_A = 25°C)	Reg_{line}	–	1.0	10	mV
Input Bias Current (V_{FB} = 0 V)	I_{IB}	–	−0.3	−1.0	µA
Open Loop Voltage Gain	A_{VOL}	65	85	–	dB
Gain Bandwidth Product (T_A = 25°C)	GBW	0.7	1.0	–	MHz
Output Source Current (V_O = 4.0 V, V_{FB} = 2.3 V)	I_{Source}	0.25	0.5	0.75	mA
Output Voltage Swing High State (I_{Source} = 0.2 mA, V_{FB} = 2.3 V) Low State (I_{Sink} = 0.4 mA, V_{FB} = 2.7 V)	 V_{OH} V_{OL}	 5.0 –	 5.7 2.1	 – 2.44	V
MULTIPLIER					
Dynamic Input Voltage Range Multiplier Input (Pin 3) Compensation (Pin 2)	 $V_{Pin\ 3}$ $V_{Pin\ 2}$	 0 to 2.5 V_{FB} to (V_{FB} + 1.0)	 0 to 3.5 V_{FB} to (V_{FB} + 1.5)	 – –	V
Input Bias Current (V_{FB} = 0 V)	I_{IB}	–	−0.3	−1.0	µA
Multiplier Gain ($V_{Pin\ 3}$ = 0.5 V, $V_{Pin\ 2}$ = V_{FB} + 1.0 V) (Note 2)	K	0.4	0.62	0.8	1/V
ZERO CURRENT DETECTOR					
Input Threshold Voltage (V_{in} Increasing)	V_{th}	1.3	1.6	1.8	V
Hysteresis (V_{in} Decreasing)	V_H	40	110	200	mV
Input Clamp Voltage High State (I_{DET} = 3.0 mA) Low State (I_{DET} = −3.0 mA)	 V_{IH} V_{IL}	 6.1 0.3	 6.7 0.7	 – 1.0	V

NOTES: 1. Maximum package power dissipation limits must be observed.

2. $K = \dfrac{\text{Pin 4 Threshold Voltage}}{V_{Pin\ 3}(V_{Pin\ 2} - V_{FB})}$

3. T_{low} = 0°C for MC34261 = −40°C for MC33261 T_{high} = +70°C for MC34261 = +85°C for MC33261

ELECTRICAL CHARACTERISTICS (V_{CC} = 12 V, for typical values T_A = 25°C, for min/max values T_A is the operating ambient temperature range that applies [Note 3], unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
CURRENT SENSE COMPARATOR					
Input Bias Current ($V_{Pin\ 4}$ = 0 V)	I_{IB}	–	–0.5	–2.0	µA
Input Offset Voltage ($V_{Pin\ 2}$ = 1.1 V, $V_{Pin\ 3}$ = 0 V)	V_{IO}	–	3.5	15	mV
Delay to Output	$t_{PHL\ (in/out)}$	–	200	400	ns
DRIVE OUTPUT					
Output Voltage (V_{CC} = 12 V)					V
Low State (I_{Sink} = 20 mA)	V_{OL}	–	0.3	0.8	
(I_{Sink} = 200 mA)		1.8	2.4	3.3	
High State (I_{Source} = 20 mA)	V_{OH}	9.8	10.3	–	
(I_{Source} = 200 mA)		7.8	8.3	8.8	
Output Voltage (V_{CC} = 30 V) High State (I_{Source} = 20 mA, C_L = 15 pF)	$V_{O(max)}$	14	16	18	V
Output Voltage Rise Time (C_L = 1.0 nF)	t_r	–	50	120	ns
Output Voltage Fall Time (C_L = 1.0 nF)	t_f	–	50	120	ns
Output Voltage with UVLO Activated (V_{CC} = 7.0 V, I_{Sink} = 1.0 mA)	$V_{OH(UVLO)}$	–	0.2	0.8	V
RESTART TIMER					
Restart Time Delay	t_{DLY}	150	400	–	µs
UNDERVOLTAGE LOCKOUT					
Startup Threshold (V_{CC} Increasing)	V_{th}	9.2	10.0	10.8	V
Minimum Operating Voltage After Turn–On (V_{CC} Decreasing)	$V_{Shutdown}$	7.0	8.0	9.0	V
Hysteresis	V_H	1.75	2.0	2.5	V
TOTAL DEVICE					
Power Supply Current	I_{CC}				mA
Startup (V_{CC} = 7.0 V)		–	0.3	0.5	
Operating		–	7.1	12	
Dynamic Operating (50 kHz, C_L = 1.0 nF)		–	9.0	20	
Power Supply Zener Voltage	V_Z	30	36	–	V

NOTES: 1. Maximum package power dissipation limits must be observed.

2. $K = \dfrac{\text{Pin 4 Threshold Voltage}}{V_{Pin\ 3}(V_{Pin\ 2} - V_{FB})}$

3. T_{low} = 0°C for MC34261, = –40°C for MC33261; T_{high} = +70°C for MC34261, = +85°C for MC33261

Figure 1. Current Sense Input Threshold versus Multiplier Input

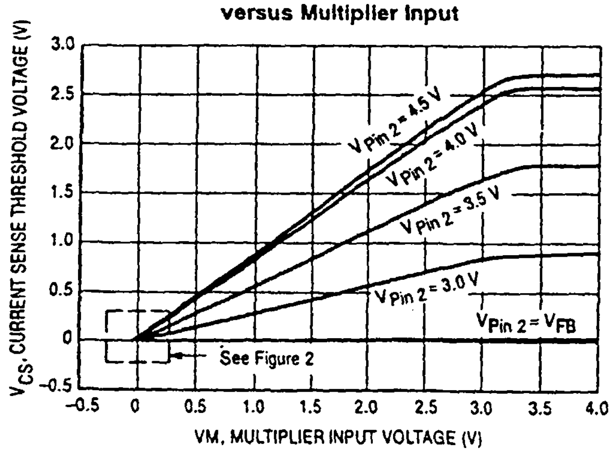


Figure 2. Current Sense Input Threshold versus Multiplier Input

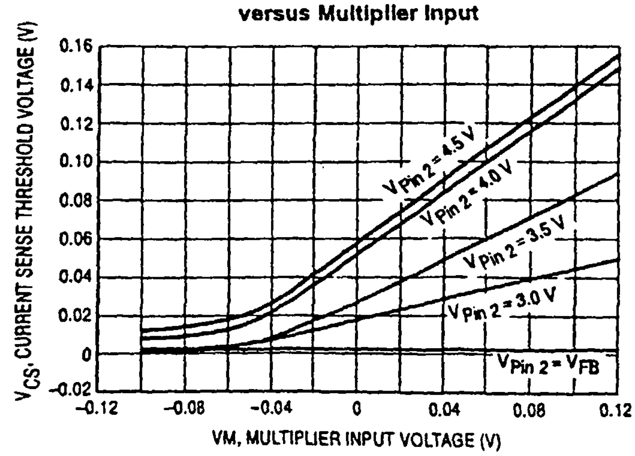


Figure 3. Voltage Feedback Input Threshold Change versus Temperature

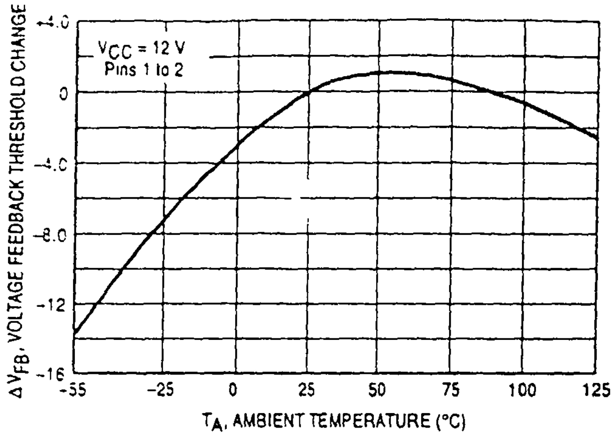


Figure 4. Error Amp Open Loop Gain and Phase versus Frequency

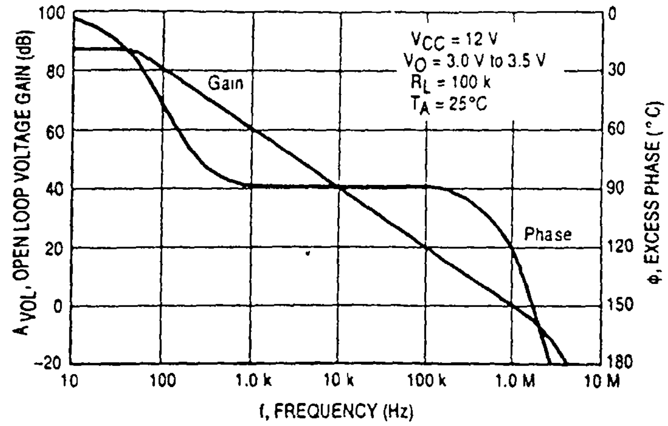


Figure 5. Error Amp Small Signal Transient Response

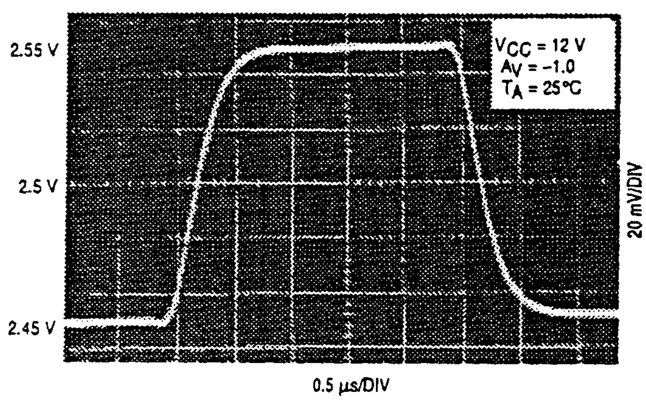


Figure 6. Error Amp Large Signal Transient Response

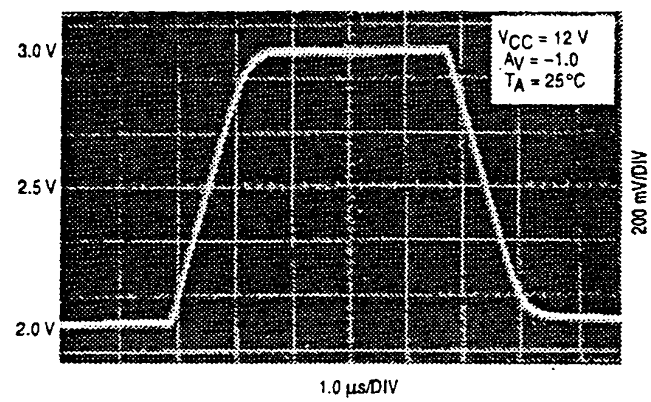


Figure 7. Error Amp Output Saturation versus Sink Current

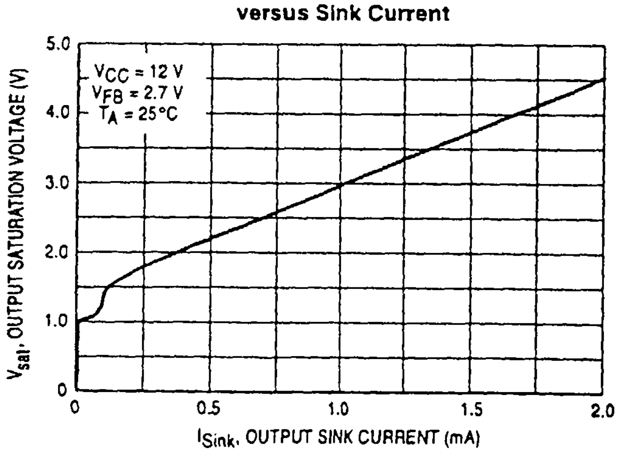


Figure 8. Restart Time Delay versus Temperature

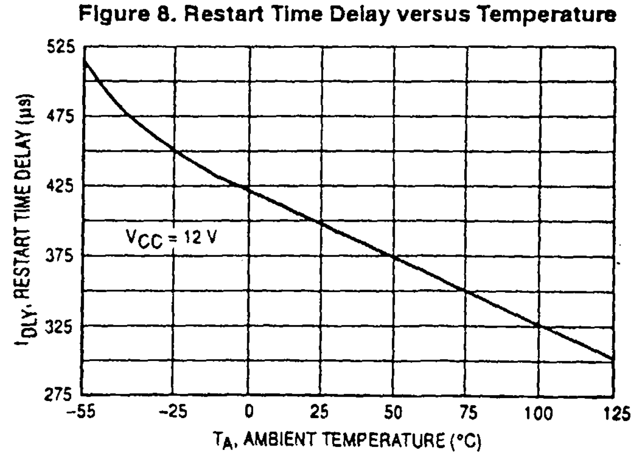


Figure 9. Zero Current D tector Input Thresh ld Voltag Change v rsus Temperature

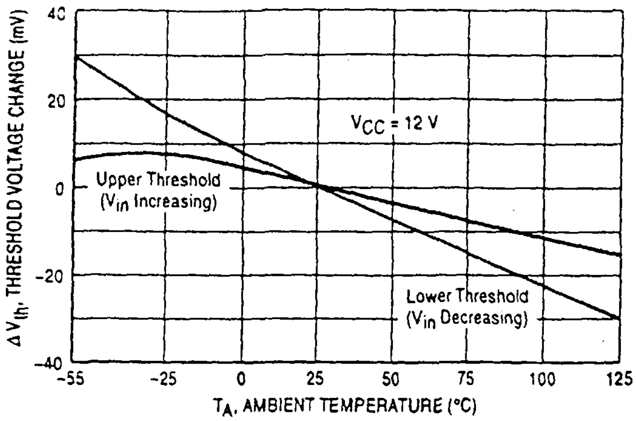


Figure 10. Output Saturation Voltag versus Load Current

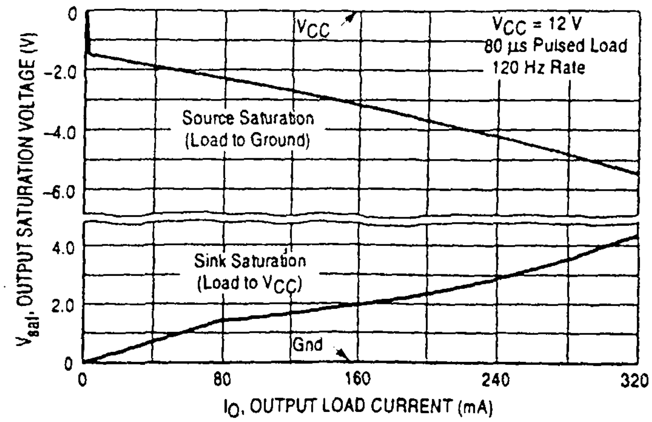


Figure 11. Drive Output Waveform

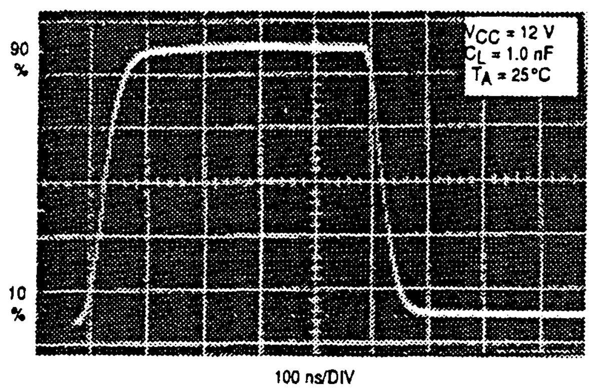


Figure 12. Drive Output Cross Conduction

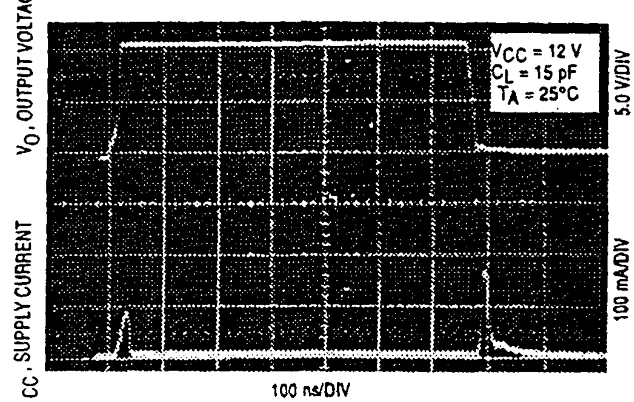


Figure 13. Supply Current versus Supply Voltage

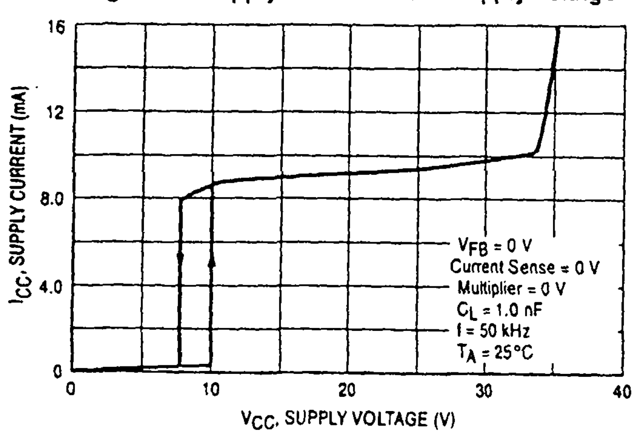
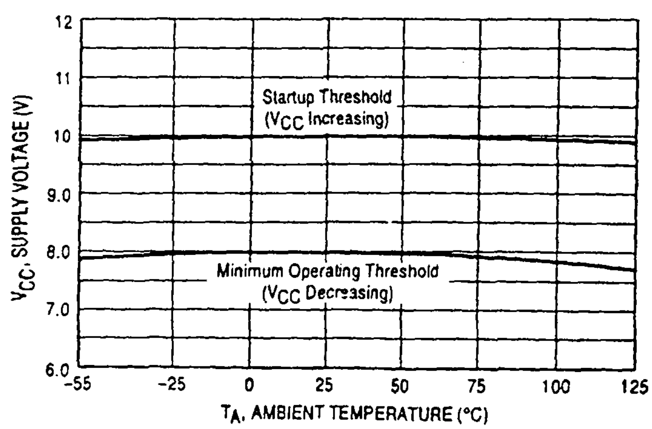


Figure 14. Undervoltage Lockout Thresholds versus Temperature



FUNCTIONAL DESCRIPTION

Introduction

Most electronic ballasts and switching power supplies use a bridge rectifier and a filter capacitor to derive raw dc voltage from the utility ac line. This simple rectifying circuit draws power from the line when the instantaneous ac voltage exceeds the capacitor's voltage. This occurs near the line voltage peak and results in a high charge current spike. Since power is only taken near the line voltage peaks, the resulting spikes of current are extremely nonsinusoidal with a high content of harmonics. This results in a poor power factor condition where the apparent input power is much higher than the real power.

The MC34261, MC33261 are high performance, critical conduction, current mode power factor controllers specifically designed for use in off–line active preconverters. These devices provide the necessary features required to significantly enhance poor power factor loads by keeping the ac line current sinusoidal and in phase with the line voltage. With proper control of the preconverter, almost any complex load can be made to appear resistive to the ac line, thus significantly reducing the harmonic current content.

Operating Description

The MC34261, MC33261 contains many of the building blocks and protection features that are employed in modern high performance current mode power supply controllers. There are, however, two areas where there is a major difference when compared to popular devices such as the UC3842 series. Referring to the block diagram in Figure 15, note that a multiplier has been added to the current sense loop and that this device does not contain an oscillator. A description of each of the functional blocks is given below.

Error Amplifier

A fully compensated Error Amplifier with access to the inverting input and output is provided. It features a typical dc voltage gain of 85 dB, and a unity gain bandwidth of 1.0 MHz with 58° of phase margin (Figure 4). The noninverting input is internally biased at 2.5 V ±2.0% and is not pinned out. The output voltage of the power factor converter is typically divided down and monitored by the inverting input. The maximum input bias current is –1.0 µA which can cause an output voltage error that is equal to the product of the input bias current and the value of the upper divider resistor R_2. The Error Amp Output is internally connected to the Multiplier and is pinned out (Pin 2) for external loop compensation. Typically, the bandwidth is set below 20 Hz, so that the Error Amp output voltage is relatively constant over a given ac line cycle. The output stage consists of a 500 µA current source pull–up with a Darlington transistor pull–down. It is capable of swinging from 2.1 V to 5.7 V, assuring that the Multiplier can be driven over its entire dynamic range.

Multiplier

A single quadrant, two input multiplier is the critical element that enables this device to control power factor. The ac haversines are monitored at Pin 3 with respect to ground while the Error Amp output at Pin 2 is monitored with respect to the Voltage Feedback Input threshold. A graph of the Multiplier transfer curve is shown in Figure 1. Note that both inputs are extremely linear over a wide dynamic range, 0 V to 3.2 V for the Multiplier input (Pin 3), and 2.5 V to 4.0 V for the Error Amp output (Pin 2). The Multiplier output controls the Current Sense Comparator threshold (Pin 4) as the ac voltage traverses sinusoidally from zero to peak line. This has the effect of forcing the MOSFET peak current to track the input line voltage, thus making the preconverter load appear to be resistive.

$$\text{Pin 4 Threshold} \approx 0.62(V_{Pin\ 2} - V_{FB})V_{Pin\ 3}$$

Zero Current Detector

The MC34261 operates as a critical conduction current mode controller, whereby output switch conduction is initiated by the Zero Current Detector and terminated when the peak inductor current reaches the threshold level established by the Multiplier output. The Zero Current Detector initiates the next on–time by setting the RS Latch at the instant the inductor current reaches zero. This critical conduction mode of operation has two significant benefits. First, since the MOSFET cannot turn on until the inductor current reaches zero, the output rectifier's reverse recovery time becomes less critical allowing the use of an inexpensive rectifier. Second, since there are no deadtime gaps between cycles, the ac line current is continuous thus limiting the peak switch to twice the average input current.

The Zero Current Detector indirectly senses the inductor current by monitoring when the auxiliary winding voltage falls below 1.6 V. To prevent false tripping, 110 mV of hysteresis is provided. The Zero Current Detector input is internally protected by two clamps. The upper 6.7 V clamp prevents input overvoltage breakdown while the lower 0.7 V clamp prevents substrate injection. Device destruction can result if this input is shorted to ground. An external resistor must be used in series with the auxiliary winding to limit the current through the clamps.

Current Sense Comparator and RS Latch

The Current Sense Comparator RS Latch configuration ensures that only a single pulse appears at the Drive Output during a given cycle. The inductor current is converted to a voltage by inserting a ground referenced sense resistor R_9 in series with the source of output switch Q1. This voltage is monitored by the Current Sense Input and compared to the Multiplier output voltage. The peak inductor current is controlled by the threshold voltage of Pin 4 where:

$$I_{pk} = \frac{\text{Pin 4 Threshold}}{R_9}$$

With the component values shown in Figure 16, the Current Sense Comparator threshold, at the peak of the haversine varies from 1.1 V at 90 Vac to 100 mV at 268 Vac. The Current Sense Input to Drive Output propagation delay is typically 200 ns.

Timer

A watchdog timer function was added to the IC to eliminate the need for an external oscillator when used in stand alone applications. The Timer provides a means to automatically start or restart the preconverter if the Drive Output has been off for more than 400 µs after the inductor current reaches zero.

Undervoltage Lockout

An Undervoltage Lockout comparator guarantees that the IC is fully functional before enabling the output stage. The positive power supply terminal (V_{CC}) is monitored by the UVLO comparator with the upper threshold set at 10 V and the lower threshold at 8.0 V (Figure 14). In the standby mode, with V_{CC} at 7.0 V, the required supply current is less than 0.5 mA (Figure 13). This hysteresis and low startup current allow the implementation of efficient bootstrap startup techniques, making these devices ideally suited for wide input range off line preconverter applications. An internal 36 V clamp has been added from V_{CC} to ground to protect the IC and capacitor C_5 from an overvoltage condition. This feature is desirable if external circuitry is used to delay the startup of the preconverter.

Output

The MC34261/MC33261 contain a single totem pole output stage specifically designed for direct drive of power MOSFETs. The Drive Output is capable of up to ±500 mA peak current with a typical rise and fall time of 50 ns with a 1.0 nF load. Additional internal circuitry has been added to keep the Drive Output in a sinking mode whenever the Undervoltage Lockout is active. This characteristic eliminates the need for an external gate pull–down resistor. The totem pole output has been optimized to minimize cross conduction current during high speed operation. The addition of two 10 Ω resistors, one in series with the source output transistor and one in series with the sink output transistor, reduces the cross conduction current, as shown in Figure 12. A 16 V clamp has been incorporated into the output stage to limit the high state V_{OH}. This prevents rupture of the MOSFET gate when V_{CC} exceeds 20 V.

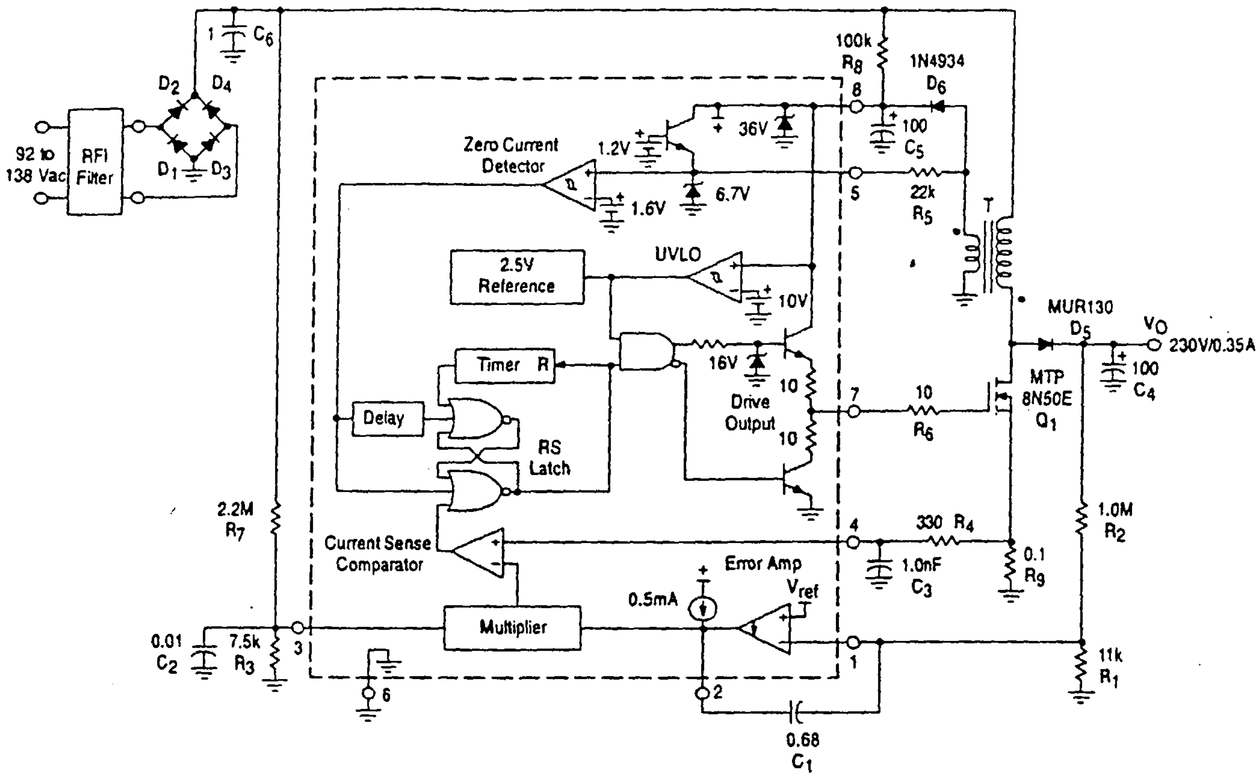
Table 1. Design Equations

Notes	Calculation	Formula
Calculate the maximum required output power.	Required Converter Output Power	$P_O = V_O\, I_O$
Calculated at the minimum required ac line for regulation. Let the efficiency η = 0.95.	Peak Inductor Current	$I_{L(pk)} = \dfrac{2\sqrt{2}\,P_O}{\eta Vac_{(LL)}}$
Let the switching cycle t = 20 µs.	Inductance	$L = \dfrac{2t\left(\dfrac{V_O}{\sqrt{2}} - Vac\right)Vac^2}{V_O\, Vac_{(LL)}\, I_{L(pk)}}$
In theory the on–time t_{on} is constant. In practice t_{on} tends to increase at the ac line zero crossings due to the charge on capacitor C_6.	Switch On–Time	$t_{on} = \dfrac{2\, P_O\, L}{\eta\, Vac^2}$
The off–time t_{off} is greatest at peak ac line and approaches zero at the ac line zero crossings. Theta (θ) represents the angle of the ac line voltage.	Switch Off–Time	$t_{off} = \dfrac{t_{on}}{\dfrac{V_O}{\sqrt{2}\,Vac\,\lvert\sin\theta\rvert} - 1}$
The minimum switching frequency occurs at peak ac line and increases as t_{off} decreases.	Switching Frequency	$f = \dfrac{1}{t_{on} + t_{off}}$
Set the current sense threshold V_{CS} to 1.0 V for universal input (85 Vac to 265 Vac) operation and to 0.5 V for fixed input (92 Vac to 138 Vac, or 184 to 276 Vac) operation.	Peak Switch Current	$R_9 = \dfrac{V_{CS}}{I_{L(pk)}}$
Set the multiplier input voltage V_M to 3.0 V at high line. Empirically adjust V_M for the lowest distortion over the ac line range while guaranteeing startup at minimum line.	Multiplier Input Voltage	$V_M = \dfrac{Vac\,\sqrt{2}}{\left(\dfrac{R_7}{R_3} + 1\right)}$
The $I_{IB}\, R_1$ error term can be minimized with a divider current in excess of 100 µA.	Converter Output Voltage	$V_O = V_{ref}\left(\dfrac{R_2}{R_1} + 1\right) - I_{IB}\, R_2$
The bandwidth is typically set to 20 Hz for minimum output ripple over the ac line haversine.	Error Amplifier Bandwidth	$BW = \dfrac{1}{2\pi \dfrac{R_1 R_2}{R_1 + R_2} C_1}$

The following converter characteristics must be chosen:

V_O – Desired output voltage
I_O – Desired output current
Vac – AC RMS line voltage
$Vac_{(LL)}$ – AC RMS low line voltage

Figure 15. 80 W Power Factor Controller



Power Factor Controller Test Data

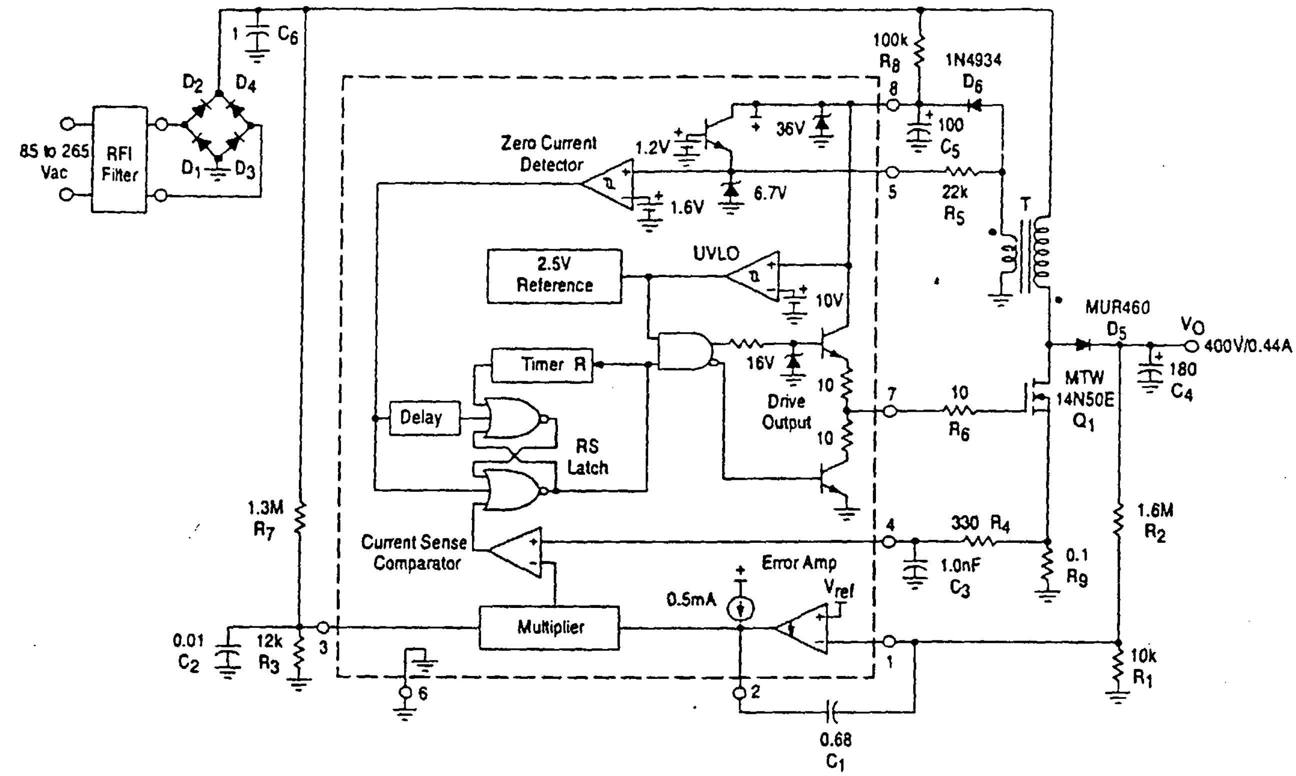
AC Line Input								DC Output				
			Current Harmonic Distortion (%)									
V_{rms}	P_{in}	PF	THD	2	3	5	7	$V_{O(pp)}$	V_O	I_O	P_O	n(%)
90	85.6	–0.998	2.4	0.11	0.52	1.3	0.67	10.0	230	0.350	80.5	94.0
100	85.1	–0.997	5.0	0.13	1.7	2.4	1.4	10.1	230	0.350	80.5	94.6
110	84.8	–0.997	5.3	0.12	2.5	2.6	1.5	10.2	230	0.350	80.5	94.9
120	84.5	–0.997	5.8	0.12	3.2	2.7	1.4	10.2	230	0.350	80.5	95.3
130	84.2	–0.996	6.6	0.12	4.0	2.8	1.5	10.2	230	0.350	80.5	95.6
138	84.1	–0.995	7.2	0.13	4.5	3.0	1.6	10.2	230	0.350	80.5	95.7

This data was taken with the test set–up shown in Figure 17.

T = Coilcraft N2881–A
Primary: 62 turns of # 22 AWG
Secondary: 5 turns of # 22 AWG
Core: Coilcraft PT2510, EE 25
Gap: 0.072" total for a primary inductance of 320 μH

Heatsink = AAVID Engineering Inc. 5903B, or 5930B

Figure 16. 175 W Universal Input Power Factor Controller



Power Factor Controller Test Data

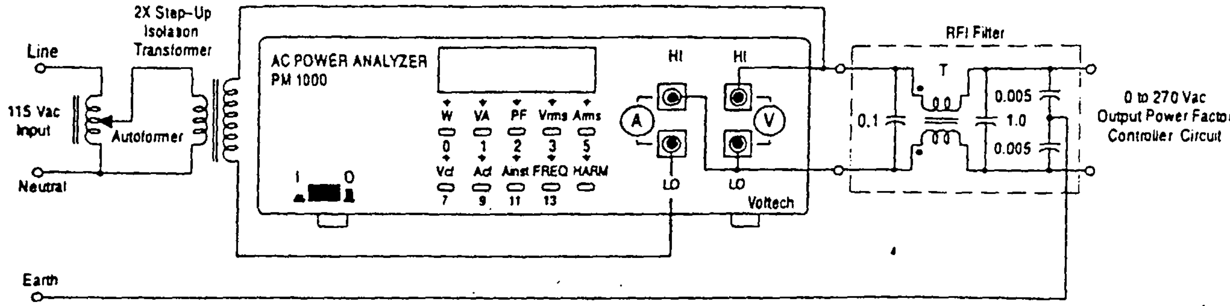
AC Line Input								DC Output				
			Current Harmonic Distortion (%)									
V_{rms}	P_{in}	PF	THD	2	3	5	7	$V_{O(pp)}$	V_O	I_O	P_O	n(%)
90	187.5	–0.998	2.0	0.10	0.98	0.90	0.78	8.0	400.7	0.436	174.7	93.2
120	184.6	–0.997	1.8	0.09	1.3	1.3	0.93	8.0	400.7	0.436	174.7	94.6
138	183.6	–0.997	2.3	0.05	1.6	1.5	1.0	8.0	400.7	0.436	174.7	95.2
180	181.0	–0.995	4.3	0.16	2.5	2.0	1.2	8.0	400.6	0.436	174.7	95.6
240	179.3	–0.993	6.0	0.08	3.7	2.7	1.4	8.0	400.6	0.436	174.7	97.4
268	178.6	–0.992	6.7	0.16	2.8	3.7	1.7	8.0	400.6	0.436	174.7	97.8

This data was taken with the test set-up shown in Figure 17.

T = Coilcraft N2880-A
Primary: 78 turns of # 16 AWG
Secondary: 6 turns of # 18 AWG
Core: Coilcraft PT4215, EE 42-15
Gap: 0.104" total for a primary inductance of 870 µH

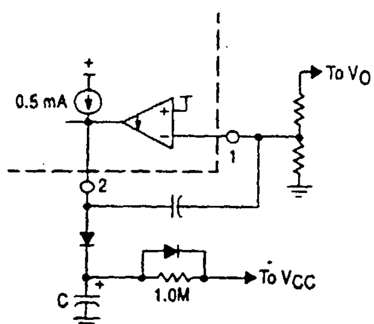
Heatsink = AAVID Engineering Inc. 5903B

Figure 17. Power Factor Test Set–Up



An RFI filter is required for best performance when connecting the preconverter directly to the AC line. Commercially available two stage filters such as the Delta Electronics 03DPCG5 work excellent. The simple single stage test filter shown above can easily be constructed with a common mode transformer. Transformer (T) is a Coilcraft CMT3–28–2 with 28 mH minimum inductance and a 2.0 A maximum current rating.

Figure 18. Soft–Start Circuit



$t_{Soft-Start} = 9000C$ in µF

Startup overshoot can be eliminated with the addition of a Soft–Start circuit.

Figure 19. Error Amp Compensation

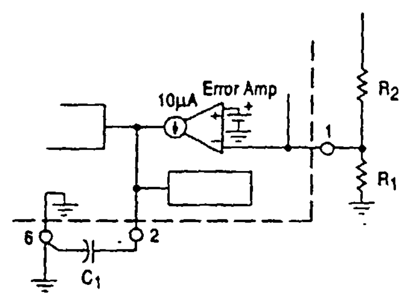
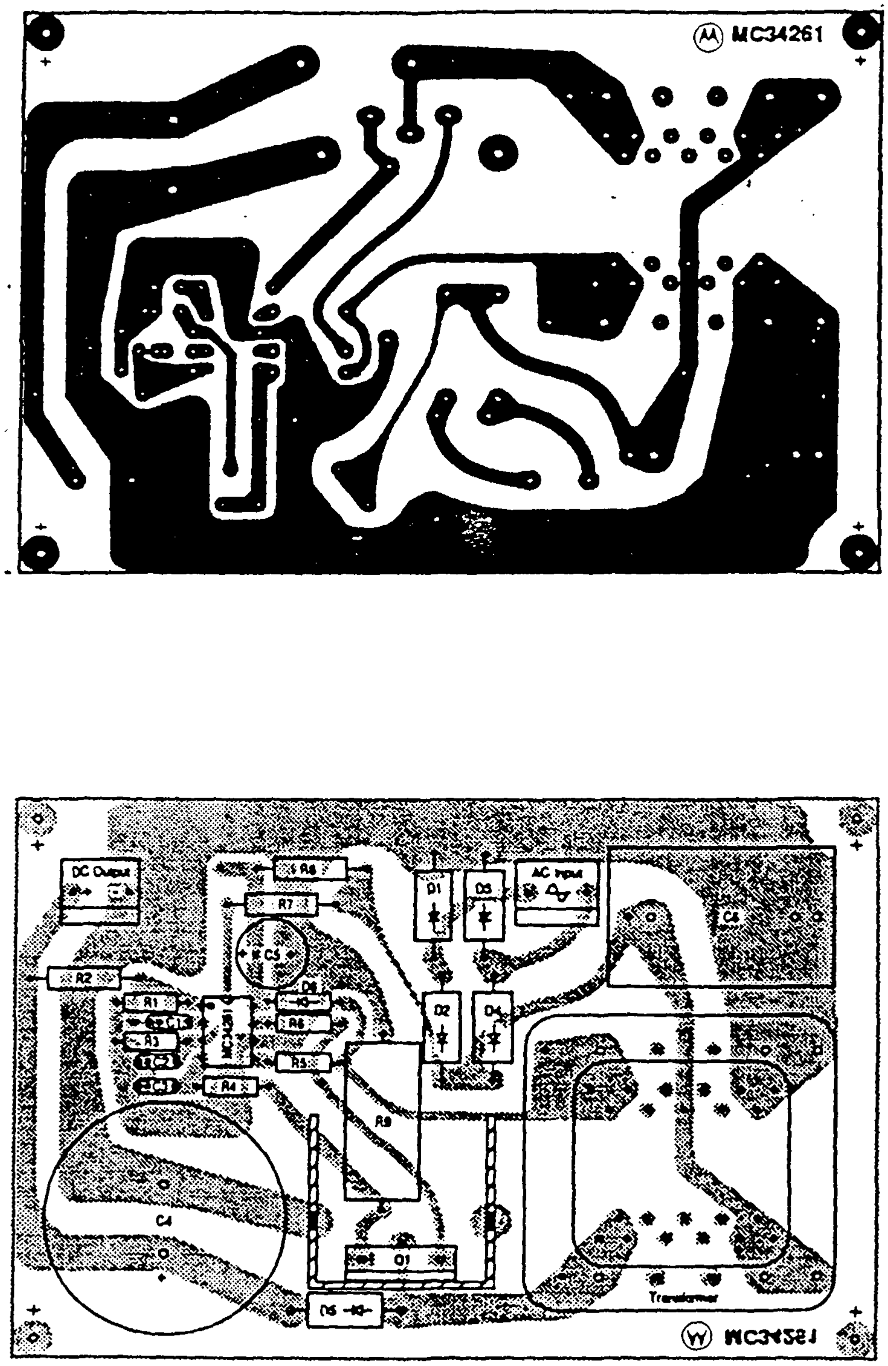
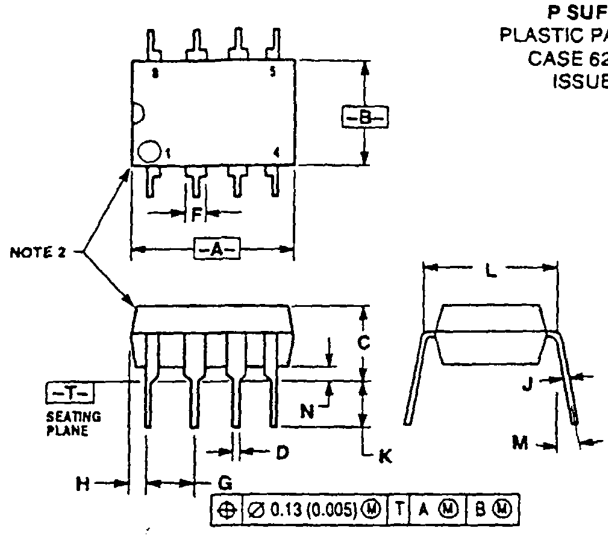


Figure 20. Printed Circuit Board and Component Layout
(Circuits of Figures 15 and 16)



OUTLINE DIMENSIONS

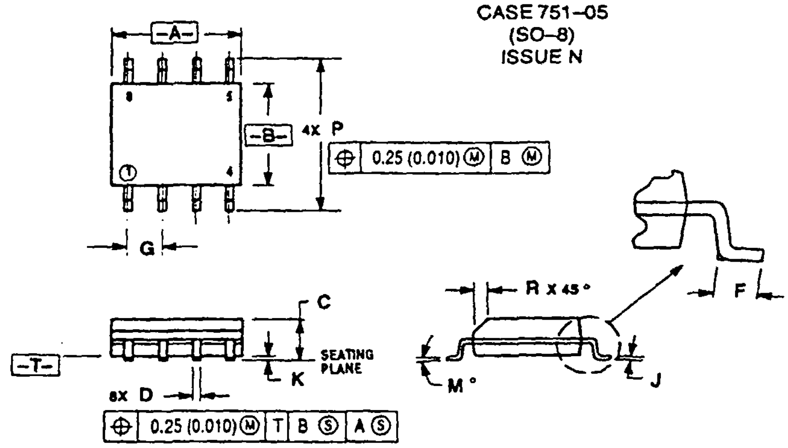
P SUFFIX
PLASTIC PACKAGE
CASE 626–05
ISSUE K



NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	—	10°	—	10°
N	0.76	1.01	0.030	0.040

D SUFFIX
PLASTIC PACKAGE
CASE 751–05
(SO–8)
ISSUE N



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.196
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.18	0.25	0.007	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

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INTERNET: http://motorola.com/sps

MOTOROLA

3 of 3 DOCUMENTS

RELUME CORPORATION, Plaintiff, v. DIALIGHT CORPORATION, ECOLUX, INC., PRECISION SOLAR CONTROLS, INC., LUMILEDS LIGHTING BV, PHILIPS LIGHTING BV, and HEWLETT-PACKARD COMPANY, Defendants.

Case No. 98-CV-72360

UNITED STATES DISTRICT COURT FOR THE EASTERN DISTRICT OF MICHIGAN, SOUTHERN DIVISION

63 F. Supp. 2d 788; 1999 U.S. Dist. LEXIS 13116

August 26, 1999, Decided
August 26, 1999, Filed

DISPOSITION: [**1] Dialight's, Precision's and Lumileds' motions for noninfringement GRANTED on issue of literal noninfringement as to all asserted claims of '645 and '909 patents. Ecolux's motion for noninfringement GRANTED on issue of literal noninfringement as to all asserted claims of '645 patent but DENIED on same issue as to asserted claims of '909 patent. Lumileds' anticipation motion GRANTED as to claim 1 of '645 patent and claims 1-3, 7, 10-12 and 16 of '909 patent but DENIED as to claims 2 and 4 of '645 patent. Lumileds' obviousness motion GRANTED as to claims 2, 4, 5 and 6 of '645 patent and claims 6, 9, 15 and 18 of '909 patent.

LexisNexis (TM) HEADNOTES - Core Concepts:

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For HEWLETT-PACKARD, LUMILEDS LIGHTING, PHILIPS LIGHTING, Defendants: James R. Case, Kerr, Russell & Webber, PLC, Detroit, MI.

JUDGES: John Feikens, United States District Judge.

OPINIONBY: John Feikens

OPINION:

[*791] **OPINION AND ORDER**

Introduction

Before me is a multi-patent infringement dispute between competitors in the light emitting diode ("LED")

traffic signal industry. At issue are summary judgment motions regarding patent noninfringement and validity filed by defendants Dialight Corporation ("Dialight"), Ecolux, Inc. ("Ecolux"), Precision Solar Controls, Inc. ("Precision"), Lumileds Lighting BV ("Lumileds"), Philips Lighting BV ("Philips"), and Hewlett-Packard Company ("Hewlett-Packard").

[**3] **I. Background**

All parties are involved in the design, development, manufacture, assembly, and/or sales of LED traffic signals. Most traffic signals in the United States use incandescent light bulbs, which produce light by heating a filament in the bulb's vacuum chamber with electric current. The heated filament gives off light. Simple incandescence is inefficient, however, since it wastes most of the electrical energy it consumes as heat.

LEDs offer a solution to this problem because they do not use a heated filament to produce light. Instead they use a tiny piece of specially formulated semiconductor material that emits light when an electric current passes through it. LEDs have existed for decades, and so has knowledge of their energy savings advantage over incandescent bulbs, but their use in traffic signals is a relatively new application.

On June 27, 1996, Peter Hochstein, a Relume employee, filed a patent application with the U.S. Patent Office, in which he claimed a variety of power supply inventions for retrofit LED arrays, i.e., arrays that can replace incandescent bulbs in devices originally built for incandescent illumination. On August 26, 1997, the Patent Office [**4] issued that application as U.S. Patent No. *5,661,645* ("the *'645* patent"). The *'645* patent lists Hochstein as its inventor.

On January 10, 1997, Hochstein filed another patent application with the Patent Office, in which he claimed various inventions related to a temperature compensation circuit for LEDs. This circuit functions as a feedback loop to prevent an LED's light intensity from decreasing as temperature increases. On July 21, 1998, the Patent Office issued this second application as U.S. Patent No. *5,783,909*. The *'909* patent lists Hochstein as its inventor.

Relume's suit against defendants alleges infringement of its *'645* and *'909* patents. All defendants have argued in response that their accused products do not infringe Relume's patents. Three defendants - Lumileds, Philips, and Hewlett-Packard (collectively "Lumileds") - have also argued that Relume's patents are invalid and unenforceable in light of relevant prior art [*792] Relume did not make available to the Patent Office during the prosecution of its patents. Defendants' summary judgment motions address these issues. Relume has filed no summary judgment motions.

II. Summary Judgment Standard

Federal Rule of Civil [**5] Procedure 56(c) provides that a summary judgment shall issue "if the pleadings, depositions, answers to interrogatories, and admissions on file, together with the affidavits, if any, show that there is no genuine issue as to any material fact and that the moving party is entitled to a judgment as a matter of law." A genuine issue of material fact does not exist "where the record taken as a whole could not lead a rational trier of fact to find for the nonmoving party." *Matsushita Elec. Indus. Co. v. Zenith Radio Corp., 475 U.S. 574, 587, 89 L. Ed. 2d 538, 106 S. Ct. 1348 (1986).* The movant has the initial burden of showing that no genuine issue of material fact exists. See *Celotex Corp. v. Catrett, 477 U.S. 317, 323, 91 L. Ed. 2d 265, 106 S. Ct. 2548 (1986);* see also Fed. R. Civ. P. 56(c).

Once the movant meets this initial burden, the nonmovant "must set forth specific facts showing that there is a genuine issue for trial." Fed. R. Civ. P. 56(e). These specific facts must constitute "sufficient evidence favoring the nonmoving party." *Anderson v. Liberty Lobby, Inc., 477 U.S. 242, 249, 91 L. Ed. 2d 202, 106 S. Ct. 2505 (1986).* [**6] Evidence that is "merely colorable" or "not significantly probative" will not demonstrate a need for trial. *Id. at 249-50.* Likewise, "the mere existence of a scintilla of evidence in support of the [nonmovant's] position will be insufficient; there must be evidence on which the jury could *reasonably* find for the [nonmovant]." *Id. at 252* (emphasis added).

The essence of the summary judgment inquiry is this: "whether the evidence presents a sufficient disagreement to require submission to a jury or whether it is so one-sided that one party must prevail as a matter of law." *Id. at 251-52.* In addressing this inquiry, I must view the evidence, and all reasonable inferences drawn from it, "in the light most favorable to the party opposing the motion." *Matsushita, 475 U.S. at 587.*

III. Literal Infringement

In their summary judgment motions, all defendants assert literal noninfringement of claims 1, 2, 4, 5, and 6 of the *'645* patent. As to the *'909* patent, all defendants except Precision n1 assert literal noninfringement of claims 1 and 10 - the independent claims of that patent. Defendants also assert [**7] noninfringement of the *'645* and *'909* patents under the doctrine of equivalents.

n1 Precision has not offered noninfringement

arguments with respect to the *'909* patent because, in a letter to the court dated January 19, 1999, Relume stated that it had chosen not to allege any of the claims of its *'909* patent against Precision. There has been no change in Relume's position since.

For Relume to establish literal infringement, "every limitation set forth in a claim must be found in the accused product or process exactly." *Becton Dickinson and Co. v. C.R. Bard, Inc., 922 F.2d 792, 796 (Fed. Cir. 1990).* Determining literal infringement is a "two-step process." Id. As a first step I must determine the meaning and scope of the claims in dispute: a step "more commonly known as claim construction." *Markman v. Westview Instruments, Inc., 52 F.3d 967, 976 (Fed. Cir. 1995).* The second step requires me to compare the construed claims with the product or process accused of infringement. [**8] Id. The first step is a question of law, see *id. at 979,* while the second step is a question of fact, see *North American Vaccine v. American Cyanamid Co., 7 F.3d 1571, 1574 (Fed. Cir. 1993).*

When construing a claim under the first step, I must consider the intrinsic evidence of record: the claim language, the specification, [*793] and, if produced, the prosecution history. See *Markman, 52 F.3d at 979.* "The appropriate starting point, however, is always with the language of the asserted claim itself." *Phonometrics, Inc. v. Northern Telecom, Inc., 133 F.3d 1459, 1464 (Fed. Cir. 1998).* This is so because "the language of the claims . . . defines the bounds of the patentee's exclusive rights." *Wiener v. NEC Electronics, Inc., 102 F.3d 534, 539 (Fed. Cir. 1996).*

In construing the claim language at issue, I am guided by the principle that "claim language is interpreted to ascertain the meaning that a person of ordinary skill in the art would give to the claims in dispute." *Schering Corp. v. Amgen, Inc., 18 F. Supp. 2d 372, 380 (D. Del. 1998)* (citing *Wiener, 102 F.3d at 539).* [**9] Although words in a claim generally have their ordinary meaning, "a patentee may choose to be his own lexicographer and use terms in a manner other than their ordinary meaning, as long as the special definition of the term is clearly stated in the patent specification or file history." *Vitronics Corp. v. Conceptronic, Inc., 90 F.3d 1576, 1582 (Fed. Cir. 1996).* Even when a patentee does not give a word a special meaning, the specification still "acts as a dictionary when it expressly defines terms used in the claims or when it defines terms by implication." Id. As such, the specification is often "the single best guide to the meaning of a disputed term." Id.

If the intrinsic evidence does not resolve the ambiguities of disputed claim language, I may then consider extrinsic evidence, such as expert testimony regarding how those skilled in the art would interpret the disputed claim. See *id. at 1583.* While extrinsic evidence may be used "as an aid in arriving at the proper construction of the claim," it "may not be used to vary or contradict the otherwise unambiguous meaning of the claim." *Desper Products, Inc. v. QSound Labs., Inc., 157 F.3d 1325, 1333 (Fed. Cir. 1998).* [**10] In most cases, intrinsic evidence will suffice to resolve ambiguity, and so, in those cases, consideration of the extrinsic evidence for construction purposes would be "improper." See *Vitronics, 90 F.3d at 1583.*

Based on the record before me, I am satisfied that I can "independently assess the claims, the specification, and if necessary the prosecution history, and relevant extrinsic evidence, and declare the meaning of the claims." *Exxon Chemical Patents, Inc. v. Lubrizol Corp., 64 F.3d 1553, 1556 (Fed. Cir. 1995).* The claims I interpret are those the parties have debated with respect to their meaning and scope. I will not refer to any prosecution history because no party has placed it in issue. I emphasize that my Markman construction of the disputed claims serves only to determine the meaning a person of ordinary skill in the art would give to those claims. See *Wiener, 102 F.3d at 539.*

IV. Claim Construction

A. The *'645* Patent

Relume's *'645* patent describes an apparatus for supplying regulated voltage d.c. electrical power to an LED array. The patent has twenty-three claims, but only claims 1, 2, 4, 5, and [**11] 6 are at issue in the parties' summary judgment motions. These five claims read as follows:

> 1. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:
>
> > a rectifier means (32) having an input and an output, said rectifier means (32) being responsive to a.c. power at said input for generating rectified d.c. power at said output;
> >
> > a power factor correction converter means (38) having an input connected to said output of said rectifier means (32) and an output, said power factor

correction converter means (38) being responsive to said rectified d.c. power at said power factor correction converter means input for generating regulated voltage d.c. power at said power factor correction converter means output; and
an LED array (12) having an input connected to said output of said power factor [*794] correction converter means (38) for receiving said regulated voltage d.c. power to illuminate said LED array (12).

2. The apparatus according to claim 1 wherein said power factor correction converter means (38) is a power factor correcting and voltage regulating buck/boost switchmode converter.

* * *

4. The apparatus according to claim 1 [**12] including an electromagnetic interference filter means (28) connected to said input of said rectifier means (32) for preventing conducted interference from feeding back onto a.c. power lines (22) connected to said rectifier means input.

5. The apparatus according to claim 1 including an adaptive clamp circuit means (24) connected to said input of said rectifier means (32) for eliminating leakage current problems.

6. The apparatus according to claim 5 wherein said adaptive clamp circuit means (24) has an input adapted to be connected to a pair of a.c. power lines (22), a pair of clamp circuit output lines (26) connected to said adaptive clamp circuit means input, a voltage sensing means (48) connected across said input of said adaptive clamp circuit means (24), and a controlled load means (50) connected across said clamp circuit output lines (26) and to said voltage sensing means (48), said voltage sensing means (48) being responsive to a magnitude of a.c. voltage at said adaptive clamp circuit means input lower than a predetermined magnitude for turning on said controlled load means (50) to connect a low impedance load (60) in said controlled load means (50) across said clamp [**13] circuit output lines (26) and said voltage sensing means (48) being responsive to a magnitude of the a.c. voltage at said adaptive clamp circuit means input equal to or greater than said predetermined magnitude for turning off said controlled load means (50) to disconnect said low impedance load (60) from said clamp circuit output lines (26).

'645, 13:16 to 14:18. n2

n2 My citations to the *'645* and *'909* patents will be in the form of "patent, column: lines."

1. Claim 1

a. "LED array"

The parties' dispute over claim 1's "LED array" concerns its configuration and components. Ecolux, Dialight, and Precision argue that the "LED array" requires a series-parallel configuration of strings of LEDs with a ballast resistor n3 in each string. Lumileds supports this construction, but also argues that if I reject it, the plain meaning of "LED array" requires only a group of LEDs forming a complete unit - a broad construction that could encompass a single string of LEDs in series or a series-parallel configuration. [**14] Relume contends that the "LED array" requires a series-parallel configuration, but not ballast resistors.

n3 A ballast resistor is a resistor that limits and spreads current across a load (here the LED array). This "ballasting" function gives the resistor its name.

The parties' proposed constructions all draw on the specification of the *'645* patent for primary support. n4 Ecolux, Dialight, and Precision find their construction of "LED array" in a specification passage that describes the array's preferred embodiment: "The LED array 12 includes a plurality of strings of series connected LEDs 14 with a ballasting resistor 16 (R1, R2, R3, R4, R5,...) connected in each string." *'645*, 5:5-8. Figure 5 of the patent diagrams this preferred embodiment of the array. Numeral 12 of Figure 5 labels the LED array as all components to the right of a vertical dash line. It also refers to [*795] the specification passage relied on by the defendants and to the phrase "LED array" in the language of claim 1.

n4 The exception is the alternative, plain

meaning construction offered by Lumileds.

[**15]

Relume finds its proposed construction in a different passage of the specification than do defendants. That passage describes the preferred embodiment of the LED array as "consisting of a large number of series-parallel connected LED devices." *'645*, 6:24-25. Relume also relies on the patent's diagrams of three prior art LED arrays, all of which depict series-parallel configurations, but only one of which depicts ballast resistors. From these references - the preferred embodiment passage and the prior art diagrams - Relume argues that a person of ordinary skill in the art of LED array power supplies would understand the series-parallel configuration, but not the ballast resistors, to be a necessary part of the claimed "LED array".

My construction of "LED array" must begin with the language of claim 1. See *Phillips Petroleum Co. v. Huntsman Polymers Corp., 157 F.3d 866, 871 (Fed. Cir. 1998).* It does not mention series-parallel LED configurations or ballast resistors. All that claim 1 explicitly requires the "LED array" element to have as physical structure is 1) the LEDs in an array arrangement and 2) an input connected to the output of the power factor correction [**16] converter means.

In fact, claim 1 speaks broadly of its claimed invention. It states at the outset that it covers "an apparatus for supplying regulated voltage d.c. electrical power to an LED array." *'645*, 13:16-17. It further states that this apparatus has three major elements: a rectifier means, a power factor correction converter means, and an LED array. Thus, upon reading claim 1 in its entirety, a person of ordinary skill in this art would understand that it covers a certain kind of regulated voltage power supply for an LED array, but would not necessarily conclude that the invention's application was restricted solely to traffic signals. To put it another way, the invention described by the language of claim 1 is a relatively simple one with potentially broad application: any conceivable use for regulated voltage LED illumination.

This point is important because it informs the ordinary meaning of the phrase "LED array." By itself, the word "array" connotes nothing more than a series or orderly grouping of things. Webster's Third New International Dictionary (1986) (hereafter "Webster's") defines it variously as "a regular and imposing grouping or arrangement" and "an [**17] impressive list, series, or group of things." n5 The modifier "LED" simply tells the reader that the things arranged by the array are LEDs. Together, then, the words "LED" and "array" have a range of ordinary meaning that can cover LED configurations as simple as a string of LEDs in a series or as complicated as the series-parallel LED strings of the *'645* patent's preferred embodiment. The entirety of claim 1 does not alter this range of ordinary [*796] meaning. n6 Thus, after reading claim 1, a person of ordinary skill in the art of LED array power supplies would understand the phrase "LED array," on its face, to cover a wide scope of LED configurations, including, but not limited to, the simple series and the series-parallel.

n5 Relume argues, without reference to a dictionary or treatise, that "array" merely means "array shaped," "having a two dimensional extent, width and height." (Pl.'s Consolidated Opp. at 12.) I reject this definition. Besides being circular and at odds with Webster's, it is critically incomplete. It does not speak to the ordered nature of arranged things that the word array evokes. It is also fails to gain Relume what it wants for validity purposes: a construction of "LED array" that excludes from its scope a single string of LEDs in a series. That simple configuration does have a width and a height: it is one LED wide and however many LEDs high.

A related point: In its response to Lumileds' anticipation motion, Relume raised arguments vehemently attacking the use of dictionaries in claim construction because they are extrinsic evidence. (See Pl.'s Anticipation Opp. Mot. at 9.) Throughout my opinion, I follow the rule laid down in Vitronics, which permits me to consult dictionaries and treatises "at any time" in my claim construction so long as the dictionary's definition does not contradict the definition supplied by the intrinsic evidence of the patent. See *90 F.3d at 1584, n.6.* [**18]

n6 Some defendants suggest that the reference numeral attached to "LED array" limits the phrase's ordinary meaning by referring the reader to the diagram of the array's preferred embodiment, which shows ballast resistors in the array. I find this argument unpersuasive, however. A reference numeral is simply a convenient tool for directing the reader to an example of the element the patentee has claimed. Had the drafter wanted to incorporate the limitations of the preferred embodiment into the language of claim 1, he or she could have done so quite easily with words.

The parties' proposed constructions for "LED array" raise the issue whether the specification narrows the phrase's ordinary meaning. According to the United States Court of Appeals for the Federal Circuit ("Federal Circuit"), I "must presume that the terms in a claim mean what they say, and, unless otherwise compelled, give full effect to the ordinary and accustomed meaning of claim terms." *Johnson Worldwide Assocs., Inc. v. Zebco Corp., 175 F.3d 985, 989 (Fed. Cir. 1999).* The Federal Circuit has identified "two situations [**19] where a sufficient reason exists to require the entry of a definition of a claim term other than its ordinary and accustomed meaning." *Id. at 990.* "The first arises if the patentee has chosen to be his or her own lexicographer by clearly setting forth an explicit definition for a claim term." Id. "The second is where the term or terms chosen by the patentee so deprive the claim of clarity that there is no means by which the scope of the claim may be ascertained from the language used." Id. This second situation is not at issue here because, as I have explained, the phrase "LED array" is clear on its face.

The ballast resistor construction of "LED array" proposed by defendants is essentially an argument under the first situation. That is, defendants believe that the drafter of the *'645* patent acted as his/her own lexicographer and clearly set forth an explicit definition of "LED array" in the specification that requires ballast resistors. At a March 22, 1999 hearing, I stated an inclination for a preliminary construction of "LED array" that was consistent with defendants' construction.

After further consideration, however, I am not persuaded that I should [**20] adopt their construction, which relies entirely on a passage and a diagram that describe the preferred embodiment of claim 1's LED array. It is a fundamental rule of claim construction that "references to a preferred embodiment, such as those often present in a specification, are not claim limitations." *Laitram Corp. v. Cambridge Wire Cloth Co., 863 F.2d 855, 865 (Fed. Cir. 1988);* see also *Ekchian v. Home Depot, Inc., 104 F.3d 1299, 1302-03 (Fed. Cir. 1997).* Otherwise, "there would be no need for the claims." *SRI Int'l v. Matsushita Elec. Corp. of America, 775 F.2d 1107, 1121 (Fed. Cir. 1985).*

Claim 1 only requires its array to incorporate one component: the LEDs. No additional components are therefore necessary. Except for its description of the preferred embodiment of the array, the specification of the *'645* patent teaches nothing different. Its statement of the invention's objectives does not mention ballast resistors or claim any functional advantage related to ballast resistors. Perhaps most telling, the preferred embodiment passage relied on by defendants is itself only cursory in its reference to ballast resistors; it does [**21] not explain what advantage is to be gained by using them in the array. From the context of the *'645* patent, then, it is clear that the drafter did not intend for the preferred embodiment's use of ballast resistors to limit the full range of ordinary meaning inherent in the "LED array" phrase of claim 1.

Precision attempts to justify a ballast resistors requirement on functional [*797] grounds. As this argument goes, a person of ordinary skill in the art would understand ballast resistors to be necessary components in any voltage-regulated LED array because, without them, a voltage-regulated LED array will not illuminate well in all conditions. From an engineering standpoint, ballast resistors undoubtedly improve the performance of a voltage-regulated LED array. By limiting and spreading the current in the array, they help the LEDs maintain a more even level of illumination. Yet claim 1 recites no limitations on the array's illumination level, nor does it recite limitations for limiting and spreading current. Because their function is not essential to the claimed array, it follows that ballast resistors themselves are not essential components for that array.

Having determined that the "LED [**22] array" of claim 1 does not require ballast resistors, the question then becomes whether it also requires a certain configuration of the LEDs. Relume essentially argues that the "LED array" of claim 1 requires a series-parallel configuration of LEDs, but not necessarily the exact series-parallel example of the patent's preferred embodiment. Defendants argue that this construction improperly imports limitations from the specification into claim 1. They correctly point out the fundamental inconsistency in Relume's objection to a ballast resistors requirement, which comes from the specification, and its support for a series-parallel requirement, which also comes from the specification. Relume responds by contending that a person of ordinary skill in the art would know that a series-parallel configuration is necessary because LED string redundancy allows the array to continue to emit light in the event of a single point LED failure. n7

n7 A single point LED failure occurs when one LED in a string of connected LEDs fails, for whatever reason, to conduct electrical current and therefore emit light. This failure causes the entire LED string to fail as well. A series-parallel configuration of LED strings minimizes the impact of a single point LED failure because, even if one string is extinguished, the other

strings will continue to emit light.

[**23]

I find Relume's series-parallel construction of "LED array" unpersuasive, however, because it fails to overcome the presumption in favor of the phrase's ordinary and accustomed meaning. The language of claim 1 does not explicitly limit the "LED array" to a series-parallel configuration. Nor does it implicitly do so. As discussed above, the phrase "LED array" means on its face that the claimed element must arrange LEDs in a regular grouping. A series configuration is simply the logical minimum of this facial meaning and thus cannot be excluded from the phrase's scope. The specification supports this conclusion. It notes that both series and series-parallel configurations exist in the prior art as design choices for LED arrays. *'645*, 1:18-30.

If I were to determine that a person of ordinary skill in the art would read a series-parallel limitation into "LED array," I would violate the fundamental principle that the preferred embodiment not limit the meaning of the claims. See *Laitram, 863 F.2d at 865*. The specification does not indicate that the drafter acted as his own lexicographer and intended for the series-parallel definition of the preferred embodiment to override [**24] the ordinary meaning of "LED array." See *Zebco, 175 F.3d at 990*. Aside from the preferred embodiment, there are no explicit series-parallel definitions for claim 1's LED array set forth in the specification. The specification also does not mention a series-parallel configuration in its summary of the invention, nor in its statement of the invention's objectives. Finally, the specification's diagrams of the prior art tellingly attach "series-parallel" as an adjective to "LED array"; this further reveals that the phrase "LED array" does not inherently teach a series-parallel configuration to those in the art.

Relume falls back on a functionality argument to support its narrow construction. [*798] It contends that the LED array of claim 1 requires, at minimum, a series-parallel configuration in order to gain the benefit of LED string redundancy. But just as Precision's function argument failed, so too does Relume's. Claim 1 nowhere recites a limitation on the configuration of the LED array, nor does it state a functional advantage from a series-parallel configuration. Moreover, claim 1 states no concern for how well or how safely the LED array illuminates, only that it does. [**25] All of this makes sense given that the invention described by claim 1 is not a kind of LED array or a safer LED array, but an apparatus that supplies voltage-regulated electrical power to any kind of LED array, whatever its application.

I conclude that the intrinsic evidence of record would lead a person of ordinary skill in the art of LED array power supplies to understand the "LED array" of claim 1 to mean an orderly arrangement of LEDs - a meaning that encompasses both a simple series and a series-parallel configuration. I further conclude that a person of ordinary skill in this art would not understand the "LED array" of claim 1 to require ballast resistors.

b. "power factor correction converter means"

Lumileds argues that *35 U.S.C. § 112*, P 6 governs the construction of claim 1's "power factor correction converter means" and limits it in scope to the corresponding structure disclosed in the specification: a switchmode buck/boost converter and a commercially available power factor controller. Relume argues that *35 U.S.C. section 112*, paragraph 6 does not apply because the language "power factor correction converter" implicitly recites sufficient structure [**26] to one of ordinary skill in the art of LED array power supplies.

Claim 1 describes the "power factor correction converter means" as

> having an input connected to said output of said rectifier means (32) and an output, said power factor correction converter means (38) being responsive to said rectified d.c. power at said power factor correction converter means input for generating regulated voltage d.c. power at said power factor correction converter means output.

'645, 13:22-28. By associating the word "means" with two functions - power factor correction n8 and voltage regulation - claim 1 uses express means-plus-function language to describe the "power factor correction converter means" element. This creates a presumption that the "power factor correction converter means" is a means-plus-function element governed by *35 U.S.C. section 112*, paragraph 6. See *Al-Site Corp. v. VSI Int'l, Inc., 174 F.3d 1308, 1318 (Fed. Cir. 1999)* ("if the word "means" appears in a claim element in combination with a function, it is presumed to be a means-plus-function element to which *35 U.S.C. § 112*, P 6 applies").

> n8 The *'645* patent explains that "power factor (p.f.) is well understood in the electrical engineering community as the ratio of real power to real power plus reactive power." *'645*,2:10-12. The closer a device's power factor ratio is to one, the better its efficiency. Poor power factor

typically results when voltage and current are out of phase, but it can also result from harmonic distortion.

[**27]

Relume contends that claim 1 overcomes this presumption by reciting sufficient structure. Relume specifically argues that a person of ordinary skill in the art would understand a "power factor correction converter" to be "a switching power supply that has some control feature to improve diode conduction time and increase power factor and reduce distortion." (Pl.'s Consolidated Opp. at 22.) Relume also notes that the claim language recites a location for the "power factor correction converter means" in the invention - between the rectifier and the LED array - and describes it as having an input and an output. (See id.)

[*799] The Federal Circuit has determined that a presumption of *35 U.S.C. section 112,* paragraph 6 governance "can be rebutted if the evidence intrinsic to the patent and any relevant extrinsic evidence so warrant." *Personalized Media v. Int'l Trade Comm'n, 161 F.3d 696, 704 (Fed. Cir. 1998).* Throughout the rebuttal inquiry, "the focus remains on whether the claim as properly construed recites sufficiently definite structure to avoid the ambit of *35 U.S.C. § 112,* P 6." Id. A claim recites sufficient structure when it elaborates the structure, material, or acts necessary [**28] to perform entirely the recited function. See *Sage Products, Inc. v. Devon Industries, Inc., 126 F.3d 1420, 1427-28 (Fed. Cir. 1997).*

Close scrutiny of the term "power factor correction converter means" reveals that it implicitly elaborates sufficient structure to a person of ordinary skill in the art of power supplies. The structural device claimed is a "converter means," and its functions are "power factor correction" and "being responsive to said rectified d.c. power...for generating regulated voltage d.c. power." n9 Although perhaps unremarkable to the layperson, the word "converter" is a structurally meaningful term-of-art to those of ordinary skill in the art of power supply electronics. According to Marty Brown's Power Supply Cookbook (1994), it connotes the generic structure of a switching power supply: that is, a switch and its controller circuit. n10 See id. at 25-26. The Power Supply Cookbook also makes it clear that power factor correction and voltage regulation are typical functions for a switching power supply to perform. See id. Thus claim 1's association of "converter means" with its specified functions of power factor correction and [**29] voltage regulation would reinforce the structural connotations of "converter" to one of ordinary skill in this art.

n9 Identification of the "power factor correction" function is less obvious than the voltage regulation function because the qualifier "power factor correction" is not phrased in the "means...for" format that usually specifies a function in claim language. The "means...for" formality, however, need not be present for me to interpret "power factor correction" as an additional functional constraint on the "converter means." See *Personalized, 161 F.3d at 705* (finding that the adjective "digital" functionally constrained the word "detector" even without "means...for" language).

n10 The Power Supply Cookbook is an authoritative instructional design text for engineers in the field of power supply electronics. The background section of the *'645* patent cites it as relevant prior art. Thus I consider it to be evidence intrinsic to the *'645* patent and properly considered in my Markman construction of the claim term "converter." See *Markman, 52 F.3d at 979.*

[**30]

I conclude that the implicitly sufficient level of structural elaboration in the term "converter" removes the "power factor correction converter means" from its presumed statutory category as a means-plus-function element governed by *35 U.S.C. section 112,* paragraph 6. See *Personalized, 161 F.3d at 705* (holding that the term "detector," even though it does not "specifically evoke a particular structure," nevertheless elaborates sufficient structure because it conveys "to one knowledgeable in the art a variety of structures known as 'detectors'"); see also *Cole v. Kimberly-Clark Corp., 102 F.3d 524, 531-32 (Fed. Cir. 1996)* (affirming a district court's conclusion that the "perforation means" did not fall under *35 U.S.C. section 112,* paragraph 6 because the ordinary meaning of the term "perforation" recites sufficient structure to one of ordinary skill in the relevant art). Accordingly, I hold that a person of ordinary skill in the art of LED array power supplies would understand claim 1's "power factor correction converter means" to require the structure of a switching power supply.

c. "generating regulated voltage

Defendants argue that the plain meaning of "generating [**31] regulated voltage" excludes from the scope of claim 1 those power supplies designed to regulate current. Relume argues that because of the basic electrical principle of Ohm's Law [*800] (voltage =

current x resistance) current regulation will result in voltage regulation in a certain circumstance - specifically when resistance is constant. Relume argues that the voltage regulation performed by its invention is limited to that circumstance and, therefore, devices designed to regulate current can fall within the scope of its invention.

I begin my claim construction with the ordinary meaning of the disputed phrase. See *Phillips, 157 F.3d at 871*. The basic meaning of "generate" found in Webster's is that of a thing producing something else. n11 The meaning of "regulated" is likewise straightforward; Webster's conveys the idea of something being ordered and controlled. n12 Finally, Webster's defines "voltage" as "electric potential or potential difference expressed in volts."

n11 Webster's most pertinent definitions of "generate" are 1) "to cause to be: to bring into existence," 2) "to originate (something material) by a physical or chemical process," and 3) "to be the cause of (a state of mind, an action, or something immaterial or intangible)." [**32]

n12 Webster's most pertinent definitions of "regulate" are 1) "to reduce to order, method, or uniformity" and 2) "to fix the time, amount, degree, or rate of."

By combining these dictionary definitions, it is clear that "generating regulated voltage" means, on its face, the function of producing controlled electric potential. This function has a specialized understanding to those in the field of electronics. According to The Illustrated Dictionary of Electronics (7th ed. 1997), "voltage regulation" is "the stabilization of a voltage against fluctuations in source or load." n13 Thus, upon reading the words "regulated voltage," a person of ordinary skill in the art would understand claim 1 to require the "power factor correction converter means" to stabilize the voltage it generates against fluctuations either in the input line voltage (the source) or in the LED array (the load).

n13 Relume is correct to point out the significance of the "or" in this definition of "voltage regulation." A device need not regulate voltage against fluctuations in both source *and* load to be called voltage regulating in the art. The specification of the *'645* patent makes it clear that claim 1's "converter means" is a voltage regulator concerned only with minimizing source voltage fluctuations.

[**33]

Yet that is not all the language of claim 1 communicates regarding its voltage regulation function. As held above, the ordinary meaning of "converter" also implies to one of ordinary skill in the art the structure necessary to perform voltage regulation: a switching power supply. At its most basic, a switching power supply must have some sort of switch and a controller circuit. See Power Supply Cookbook at 25-26. For a voltage-regulating power supply, the controller circuit's "main purpose" must be "to maintain a regulated output voltage." Id. at 26. It does so by acting as a voltage feedback loop. See id. at 73.

These structural limitations implied by the ordinary meaning of "converter" cannot be ignored. Voltage regulation calls for unique componentry - for example, the controller's output voltage feedback loop. Yet there is an even more important point: a voltage-regulating power supply is a device expressly designed to stabilize the electrical property of voltage and thus generate regulated voltage. It is built to act on voltage, not current.

Relume's tortured construction of "generating regulated voltage" turns a blind eye to these realities. Relume wants claim [**34] 1 to be nonsensically construed so that any device, regardless of its design and structure, would fall within its scope so long as that device effects source voltage regulation in the limited circumstance when resistance is constant. I have a duty, however, to give meaning to all the words in claim 1 in order to determine the scope of its claimed invention; the drafter has linked the "converter means" to the "generating regulated voltage" function. Thus [*801] I cannot ignore the implicit structural limitations in the term "converter" - structural limitations, I note, that Relume urged me to recognize in order to avoid the application of *35 U.S.C. section 112*, paragraph 6 to the "converter means."

There is another flaw in Relume's construction. The much trumpeted truth of Ohm's Law is ultimately immaterial to the resolution of the claim construction question before me. All it tells me is that in a certain situation, when resistance is controlled, current-regulating and voltage-regulating power supplies will have the same effect on their output voltage. It does not tell me anything about the purpose, design, and structure of current-regulating and voltage-regulating devices in the art. Thus, while [**35] interesting, the scientific fact of Ohm's Law does not address the underlying issue posed by the construction of "generating regulated

voltage": What does it mean in the art when a converter regulates voltage instead of current?

The specification of the *'645* patent reinforces these points. In its discussion of prior art power supplies, it recognizes the distinction drawn in the art between current regulation and voltage regulation. n14 That distinction is based on meaningful engineering reasons. For instance, the specification notes that current regulation will result in better LED light output than voltage regulation. *'645*, 4:51-54. The reason: LED light output is directly related to the current flowing through the LED, not the voltage. There is of course a more obvious basis for the distinction in the art: current regulation and voltage regulation act on, and regulate, different electrical properties. Thus it is clear that treating power supplies designed for current regulation like those designed for voltage regulation - the effect of Relume's construction - would violate precepts in the art.

> n14 So too does The Illustrated Dictionary of Electronics. It gives distinct definitions for voltage regulation (quoted above) and for current regulation ("the stabilization of current at a predetermined level or value").

[**36]

There is nothing in the specification that alters my analysis of "generating regulated voltage." See *Zebco, 175 F.3d at 990.* It discloses a voltage-regulating switching power supply for the patent's invention that is structurally consistent with the ordinary meanings of "converter" and "generating regulated voltage" I discuss above:

> The converter 38 includes a power factor correction (P.F.C.) integrated circuit (I.C.) controller 40, which is a commercial device available from many sources and functions by allowing current to charge a storage capacitor C (LARGE) only in phase with the rectified a.c. voltage thereby assuring a power factor close to unity. The control I.C. 40 also provides voltage regulation in the switchmode buck/boost converter by monitoring the output voltage and adjusting the high frequency on-off switching period of the pass element commensurately.

'645, 5:41-53. Not surprisingly, the specification nowhere instructs the reader on how a current-regulating power supply could be used instead of a voltage-regulating power supply to effect the aims of the invention.

For all of the reasons discussed, then, I hold that a person of ordinary [**37] skill in the art of LED array power supplies would understand "generating regulated voltage" to mean that claim 1's "converter means" is designed to produce stabilized voltage at its output despite fluctuations in its input voltage. Because the intrinsic evidence of the patent provides a clear meaning for "generating regulated voltage," I decline to consider the extrinsic testimony of the *'645* patent's inventor, Mr. Hochstein, which Relume offers in support of its construction. See *Southwall Tech., Inc. v. Cardinal IG Co., 54 F.3d 1570, 1578 (Fed. Cir. 1995);* see also *Vitronics, 90 F.3d at 1583.*

2. Claim 2

The parties do not dispute the meaning of claim 2. As a dependent claim to claim 1, [*802] it incorporates all the limitations of claim 1, but with one exception. Instead of a generic "converter means," it teaches the use of a specific type: "a power factor correcting and voltage regulating buck/boost switchmode converter." *'645*, 13:33-36.

3. Claim 4

The parties do not dispute the meaning of claim 4. Like claim 2, it is a dependent claim to claim 1. It therefore incorporates all the limitations of claim 1 and adds another: the use of an [**38] "electromagnetic interference filter means." *'645*, 13:43. It also requires that the filter be located before the rectifier means. *'645*, 13:42-46.

4. Claim 5

This claim recites an adaptive clamp circuit means for eliminating leakage current problems. n15 *'645*, 13:47-50. Defendants contend that it is written in "means-plus-function" format and is therefore governed by *35 U.S.C. § 112,* P 6. Relume does not appear to dispute defendants' proposed construction.

> n15 Leakage current creates problems for traffic signals because it falsely triggers the conflict monitors at an intersection. Conflict monitors exist to detect and prevent two green lights in perpendicular directions. A falsely triggered conflict monitor tells the intersection's traffic lights to go to blinking red signals when there is no need.

I agree with defendants' construction. By associating

the word "means" with the function of eliminating leakage current problems, claim 5 uses express means-plus-function language to describe [**39] its "adaptive clamp circuit means" element. This creates a presumption that the "adaptive clamp circuit means" is a means-plus-function element governed by *35 U.S.C. section 112*, paragraph 6. See *Al-Site, 174 F.3d at 1318*. Unlike the dispute over the "power factor correction converter means," however, Relume has not argued that claim 5 overcomes this presumption by reciting sufficient structure. Even if Relume were to argue that point, my review of the language of claim 5 does not reveal that it elaborates sufficient structure necessary to perform entirely the recited function. See *Sage Products, 126 F.3d at 1427-28*.

Thus according to *35 U.S.C. section 112*, paragraph 6, the "adaptive clamp circuit means" of claim 5 is to be construed "to cover the corresponding structure, material, or acts described in the specification and equivalents thereof." *35 U.S.C. § 112*, P 6; see also *Lockwood v. American Airlines, Inc., 107 F.3d 1565, 1570-71 (Fed. Cir. 1997)*. Accordingly, I hold that a person of ordinary skill in the art would understand the corresponding structure described in the specification of the *'645* patent to be a voltage sensing [**40] means (48) comprised of a transistor (Q1) and a Zener diode (D5) and a controlled load means (50) comprised of a transistor (Q2) and a resistor (60). *'645*, 7:40 to 8:3. The specification explains their operation thus:

> The clamping circuit 24 works by using the sensing transistor Q1 and the Zener diode D5 (the voltage sensing means 48 of FIG. 6a) to determine if the line voltage is below a certain magnitude (typically 40 volts)....If the Zener diode D5 does not conduct, the transistor Q2 is turned on to place the load resistor 60 [across] the power lines 22 causing the leakage voltage to drop below 10 volts. The transistor Q2 and the resistor 60 are the controlled load means 50 of FIG. 6a. Whenever the traffic signal controller relay "closes", the line voltage appearing at the input to the adaptive clamping circuit 24 rises to nominally 120 volts and the sensing circuit (Q1 and D5) turn off the controlling transistor Q2, removing the resistor 60 from the circuit thereby preventing unnecessary dissipation of power.

'645, 7:53 to 8:1.

5. Claim 6

Claim 6, which depends from claim 5, merely recites the specific structure presented [*803] in the specification. Accordingly, [**41] claim 6 is similar if not identical in scope to claim 5, in spite of the doctrine of claim differentiation. See *Laitram Corp. v. Rexnord, Inc., 939 F.2d 1533, 1538 (Fed. Cir. 1991)* (finding that the doctrine of "claim differentiation" cannot override section 112, paragraph 6).

B. The *'909* Patent

Relume's *'909* patent describes an apparatus, as well as a method, that maintains the luminous intensity of an LED. The patent has 18 claims. Claims 1-3, 6, 7, 9-12, 15, 16, and 18 are at issue in the parties' motions. They read as follows:

> 1. A circuit for maintaining the luminous output of a light emitting diode, said circuit comprising:
>
> > at least one light emitting diode (LED) (12) for producing a luminous output;
> >
> > a sensor (22, 24) for sensing a condition proportional to said luminous output of said LED (12) and for producing a luminous output signal;
> >
> > a power supply (16) electrically connected to said LED (12) for supplying ON/OFF pulses of electrical energy to produce the luminous output of said LED (12); and
> >
> > said power supply (16) including a switching device responsive to said luminous output signal for adjusting the electrical energy supplied by [**42] said pulses per unit of time to adjust the average of said current passing through said LED (12) to maintain the luminous output of said LED (12) at a predetermined level.

> 2. A circuit as set forth in claim 1 wherein said sensor (22) includes means for sensing changes in temperature of said LED (12).
>
> 3. A circuit as set forth in claim 2 wherein said sensor (22) includes a predetermined temperature behavior model to establish the increase in said current passing through said LED (12) as a function of the operating temperature of said LED (12) integrated with said predetermined temperature behavior model.

* * *

6. A circuit as set forth in claim 1 wherein said switching device includes means for adjusting the electrical energy supplied by said pulses per unit of time by adjusting the frequency of said pulses.

7. A circuit as set forth in claim 1 wherein said switching device includes means for adjusting the electrical energy supplied by said pulses per unit of time by adjusting the width of said pulses.

* * *

9. A circuit as set forth in claim 1 including a filter for filtering the electrical energy supplied by said pulses into substantially d.c. supplied [**43] to said LED for producing said luminous output.

10. A method of maintaining the luminous output of a light emitting diode (LED) comprising the steps of:

> supplying ON/OFF pulses of electrical energy from an adjustable power supply (16) for establishing electrical current passing through the LED (12);
> sensing (22, 24) a condition proportional to the luminous output of the LED (12); and
> adjusting the electrical energy supplied by the ON pulses per unit of time to adjust the average of the current passing through the LED (12) to maintain the luminous output of the LED (12) at a predetermined level.

11. A method as set forth in claim 10 wherein sensing a condition is further defined as sensing changes in temperature of the LED (12).

12. A method as set forth in claim 10 further defined as establishing a predetermined [*804] temperature behavior model and increasing the current passing through the LED (12) as a function of the operating temperature of the LED (12) integrated with the predetermined temperature behavior model.

* * *

15. A method as set forth in claim 10 further defined as adjusting the electrical energy supplied by said pulses per unit of time by adjusting [**44] the frequency of said pulses.

16. A method as set forth in claim 10 further defined as adjusting the electrical energy supplied by said pulses per unit of time by adjusting the width of said pulses.

* * *

18. A method as set forth in claim 10 including filtering the output of the power supply for filtering the electrical energy supplied by said pulses into substantially d.c. supplied to the LED for producing said luminous output.

'909, 6:64-67, 7:all, and 8:all.

1. Claim 1

a. "condition proportional"

Ecolux construes "condition proportional" to mean directly proportional or having "the same or constant ratio." Ecolux believes this construction requires the invention's temperature sensor n16 to be located on the LED circuit board, as opposed to somewhere else in the invention's circuitry. Relume argues that this locational requirement is an unnecessary limitation on the claimed invention. Relume believes that the scope of "condition proportional" includes temperature sensors that are sensitive to the ambient temperature surrounding the LEDs.

> n16 The *'909* patent discloses two kinds of preferred embodiment sensors: a light sensor and a temperature sensor. Ecolux focuses its construction arguments on the temperature sensor because that is the kind of sensor its accused product uses.

[**45]

Claim 1 does not recite a limitation on the location of its sensor. It describes the "sensor" as performing two functions: "sensing a condition proportional to said luminous output of said LED (12) and...producing a luminous output signal." *'909*, 7:1-3. This language limits the possible universe of conditions that could be sensed

by the sensor to those that have a "proportional" relationship to the light output of the LEDs. n17 Webster's most relevant definition of "proportional" is "having the same or a constant ratio;" this is, in fact, Ecolux's proposed definition. n18 The key to understanding its scope is in the meaning of "ratio." Webster's defines it as "the fixed or approximate relation of one thing to another." Therefore all that claim 1 requires its sensor to do is sense a condition that has a "fixed relation" to the light emitted from the LEDs; this function does not imply a locational requirement for the invention's temperature sensor.

n17 A related point regarding the "condition" sensed: the claim language does not limit it to the temperature of the LEDs as Ecolux has also argued. It is worth repeating that the only limit on the "condition" sensed is whether it is "proportional to the luminous output of the LEDs." [**46]

n18 Ecolux's definition comes from its expert, Barry N. Feinberg. (See Ecolux's Mem. in Support of Mot. for Summ. J. of Non-Infringement at 7 & Ex. D.) He states without explanation that it is the definition given to "proportional" by those in engineering and mathematics. (See id.) To the extent that I accept "having the same or a constant ratio" as the definition of "proportional," I do so because it is the ordinary meaning of the word (as indicated in Webster's) and not because it is the opinion of Feinberg. Furthermore, in adopting this definition, I do not also adopt the alternative, "direct proportion" definition proposed by Ecolux. The claim language uses "proportional" without any qualification.

Despite the fact that the language of claim 1 neither explicitly or implicitly recites a location for the sensor, Ecolux nevertheless argues that such a requirement exists because the preferred embodiment [*805] diagram of the temperature sensor depicts it on the LED circuit board. Aside from this diagram, I find no support in the patent's specification for a locational requirement. Ecolux's [**47] argument is therefore an attempt to restrict claim language that is broader in scope than the preferred embodiment. The rules of claim construction do not permit this. See *Electro Med. Sys. S.A. v. Cooper Life Sciences, 34 F.3d 1048, 1054 (Fed. Cir. 1994)* ("particular embodiments appearing in a specification will not be read into the claims when the claim language is broader than such embodiments").

Accordingly, I hold that a person of ordinary skill in the art of LEDs would understand "condition proportional" to mean that the sensor must sense a condition that has some fixed relationship with the LEDs' light output, but would not understand the phrase to require a certain location for the sensor.

b. "ON/OFF pulses"

On the basis of some of the invention's preferred embodiments, Ecolux argues that the "ON/OFF pulses" of electrical energy called for by claim 1 must have a rectangular wave form. Relume contends that the "ON/OFF pulses" limitation does not require a specific wave form but only that the invention's power supply employ a switching action to control the current delivered to the LEDs.

Ecolux's construction ignores the clear meaning of both the claim [**48] language and the specification. Claim 1 recites no limitation on the shape of the pulses' wave form. Nor does the specification. In fact, it notes that at least two types of wave forms can be utilized by the invention: rectangular and a.c. sinusoidal. Accordingly, I hold that one of ordinary skill in the art of LEDs would understand that "ON/OFF pulses" does not limit the shape of the pulses' wave form but instead requires that a switching power supply create the pulses by turning a switch on and off.

c. "said power supply (16) including a switching device"

Relume contends that this phrase requires the switch to be located in the invention's power supply. Lumileds disagrees, arguing that the word "including" does not necessarily mean "in."

The ordinary meaning of "including" supports Relume. Webster's defines it as "serving to enclose or cover." Reference to the definition of the verb "include" is also helpful, revealing nuances like "to shut up: CONFINE, ENCLOSE, BOUND," "to place, list, or rate as a part or component of a whole," and "to take in, enfold, or comprise as a discrete or subordinate part." These definitions clearly convey the idea that the power supply of [**49] the *'909* patent embraces a switch as one of its components. The specification reflects this. By repeatedly describing the power supply as including a switch, it emphasizes to one of ordinary skill in the art that the switch is a part of the power supply.

But there is a more basic point. By having the power supply include a switch, the intrinsic evidence of the *'909*

patent is simply instructing a person of ordinary skill in the art that the power supply of the claimed invention must be a switching power supply. Thus the "including" limitation is less a locational requirement than a componentry requirement. So the specification of the *'909* patent speaks frequently of the invention's use of "a switch mode power supply." *'909*, 4:66-67. And it claims a great advantage from the inherent efficiency of such a power supply. *'909*, 4:50-51. Yet it displays no concern for the location of the switch within the power supply. As the specification states: "It will be appreciated that such a switch mode power supply can take many forms. Within the scope of the present invention, switch mode supplies include any power source 16 that is turned on and off at a frequency consistent with the other operating [**50] [*806] parameters of the system." *'909*, 4:66 to 5:3.

Accordingly, I hold that a person of ordinary skill in the art would understand "said power supply (16) including a switching device" to mean that the invention of claim 1 requires a switching power supply.

d. "maintain...at a predetermined level"

Lumileds argues that the phrase - "maintain the luminous output of said LED (12) at a predetermined level" - requires claim 1's switching power supply to adjust the current supplied to the LEDs so that their luminous output is essentially constant. Focusing solely on the meaning of the word "predetermined," Relume argues that the disputed phrase requires only that the switching power supply maintain LED light intensity at amounts that are known or modeled in advance.

The drafter's use of the word "maintain" exposes the error of Relume's construction. The idea of uniform or constant output inheres in the word's ordinary meaning. Webster's defines "maintain" as "to keep in a state of repair, efficiency, or validity: preserve from failure or decline." And it defines "predetermine" as "to settle beforehand: settle in advance." Taken together, these definitions establish that the phrase, [**51] "maintain the luminous output of said LED (12) at a predetermined level," simply means to keep the LEDs' luminous output at a level chosen beforehand. n19

n19 Here is what this construction means in practice. Suppose the desired level of LED output chosen beforehand is two units of light. The invention of claim 1 will seek to keep luminous output at this predetermined level of two units despite fluctuations in operating temperature.

The specification does not alter this construction. It states that "the present invention relates to a new method of maintaining an essentially constant luminous output from an LED array, irrespective of operating temperature." *'909*, 4:42-44. It later observes that either of its contemplated sensors -- the light sensor or the temperature sensor -- "can be used to modulate the average current through the LED array to maintain essentially constant luminous output, irrespective of operating temperature." *'909*, 5:17-20. It also describes how the invention's preferred embodiment uses a [**52] temperature behavior model "in order to keep the luminous output of the LED array essentially constant at a predetermined level." *'909*, 3:66-67. Nowhere does the specification indicate that the invention of the *'909* patent has the ability to produce anything other than essentially constant LED output.

In the end, the clear language of claim 1 and the equally clear specification of the *'909* patent demonstrate that Relume's construction of "maintain the luminous output of said LED (12) at a predetermined level" is incomplete and at odds with the ordinary meaning of "maintain." It is not enough, as Relume did in its response brief, to offer a definition for "predetermined" and then ignore the more important and relevant meaning of "maintain." The disputed phrase must be examined in its entirety in order to comprehend its full scope.

Accordingly, I hold that a person of ordinary skill in the art would understand the claim language "maintain the luminous output of the said LED (12) at a predetermined level" to charge the invention of claim 1 with the task of keeping, or preserving from decline, the luminous output of its LEDs at an amount chosen beforehand.

2. Claims 2, 3, 6, 7, and [53] 9**

The parties do not dispute the meaning of these claims, all of which depend from claim 1. Claim 2 requires that the "sensor" recited in claim 1 "include[] means for sensing changes in temperature of said LED (12)." *'909*, 7:13-15. Claim 3 requires that the temperature feedback system [*807] of the *'909* patent use a "predetermined temperature behavior model." *'909*, 7:20-21. Claim 6 specifies that the invention's switching power supply must adjust its ON/OFF pulses "by adjusting the frequency of said pulses." *'909*, 7:31-32. Claim 7 alternatively teaches a switching power supply that adjusts its ON/OFF pulses "by adjusting the width of said pulses." *'909*, 7:35-36. Finally, claim 9 requires that the invention of claim 1 include a filter for converting the ON/OFF pulses into d.c. power for the LEDs. *'909*, 7:41-44.

3. Claim 10

Claim 10 is an independent claim that recites a three-step method for "maintaining the luminous output of a light emitting diode (LED)." *'909*, 8:1-2. Dialight and Relume dispute the meaning of a phrase -- "adjustable power supply" -- in the claim's first step, which teaches "supplying ON/OFF pulses of electrical energy from an adjustable power supply (16) for [**54] establishing electrical current passing through the LED (12)." *'909*, 8:3-5. Dialight argues that the disputed phrase requires the use of a switching power supply that adjusts the frequency or pulse width of its ON/OFF current pulses in response to feedback from a sensor. Relume asserts that the "adjustable" limitation only requires a power supply that is adjustable in some broad sense, "e.g., as a voltage regulator." (Pl.'s Consolidated Opp. at 32.)

The ordinary meaning of the adjective "adjustable" provides valuable guidance, though it does not resolve the dispute. Webster's defines the word to mean "capable of being adjusted." Thus to label the invention's power supply as "adjustable" is to say that it is capable of being adjusted. I note that this implies that something acts *on* the power supply to adjust it.

The specification sharpens the reader's understanding of "adjustable" by detailing how the invention's power supply is capable of being adjusted. Thus in summarizing the claimed invention, the specification describes the power supply as including "a switching device responsive to the luminous intensity signal for adjusting the electrical energy supplied by the pulses [**55] per unit of time to adjust the average of the current passing through the LED to maintain the luminous intensity of the LED at a predetermined level." *'909*, 2:12-17. The specification also later observes that "the primary purpose of the present invention is to increase the average current through the LED array with increasing temperature, by adjusting the pulse width or frequency of LED switch mode power supply." *'909*, 4:62-65.

These overarching statements about the invention of the *'909* patent establish that the specification sets forth a specific meaning for "adjustable power supply." See *Zebco, 175 F.3d at 990.* Under that meaning, "adjustable" requires the invention's switching power supply to be responsive to a luminous intensity signal from a sensor so that the ON/OFF current pulses supplied by the power supply can be adjusted in their frequency or pulse width. In other words, the invention's power supply must be capable of being adjusted by the feedback from a sensor that measures, either directly or indirectly, the amount of light emitted by the LEDs.

For these reasons, I reject Relume's construction of "adjustable power supply." Its construction gives a vague [**56] and irrelevant meaning to the phrase that conveniently ignores the specification's description of the patent's invention. The intrinsic evidence of the *'909* patent gives full support to Dialight's construction of the disputed phrase. I therefore hold that a person of ordinary skill in the art would understand the phrase "adjustable power supply" to mean that the invention's switching power supply must be capable of being adjusted by the luminous intensity signal of a sensor. n20

n20 In support of this construction, Dialight raised additional points regarding the meaning of the third step of claim 10: "adjusting the electrical energy supplied by the ON pulses per unit of time to adjust the average of the current passing through the LED (12) to maintain the luminous output of the LED (12) at a predetermined level." In particular, Dialight argued that *35 U.S.C. § 112,* P 6 governed that step as a "step-plus-function" element and thus that the third step must be limited in scope to correspond to acts in the specification -- specifically, the sensor's act of giving feedback to the power supply. My construction of "adjustable power supply" makes this additional argument superfluous.

[**57]

[*808] **4. Claims 11, 12, 15, 16, and 18**

The parties do not dispute the meanings of these method claims, all of which depend from claim 10. Each parallels a dependent apparatus claim. For example, claim 11 takes the substance of claim 2 and gives it the nomenclature of a method claim. Likewise, claim 12 parallels claim 3, claim 15 parallels claim 6, claim 16 parallels claim 7, and claim 18 parallels claim 9.

V. Comparison with Accused Products

I now turn to the second step of the literal infringement analysis: comparing the properly construed claims with the product or process accused of infringement. See *Markman, 52 F.3d at 976.* Many infringement arguments are now moot in light of my claim construction. I address only those that survive.

A. The *'645* Patent

1. Dialight's Accused Products

Relume has accused two Dialight products of literally infringing claim 1 of its *'645* patent: Dialight's 8" and 12" LED traffic signals. Dialight argues that its products do not literally infringe claim 1 because, inter

alia, they lack a required element -- they do not generate regulated voltage.

Dialight's supporting evidence consists of a declaration [**58] by its expert, Rand Eikelberger, who is Dialight's Vice President for Engineering, and circuitry diagrams attached as exhibits to Eikelberger's declaration. Referring to these diagrams, Eikelberger states in his declaration that Dialight's accused products use "a current regulator circuit," the output of which is "regulated (i.e., constant total) current." (Eikelberger Decl. at P 4.) He explains that the regulator uses current sense resistors to provide feedback about its output so that it can change the ON/OFF ratio of its switching and thereby alter the current flowing to the LED array. (See id. at PP 11-13.) He states that he witnessed tests of Dialight's accused products, in which some strings of the LED array were purposefully shorted, and saw that the current output of the regulator remained essentially constant despite the short circuits in the array. (See id. at PP 7-8 & Ex. 2.) And he also points out that the lack of ballast resistors in Dialight's accused products is further evidence of current regulation because ballast resistors are current controlling devices that are unnecessary, even wasteful, in arrays already supplied current regulated power by a switching [**59] power supply. (See id. at PP 15-18.)

Dialight's evidence satisfies its Rule 56(c) burden of showing that no genuine issue of material fact exists because that evidence establishes that Dialight's "converter means" is designed to generate stabilized current. See *Celotex, 477 U.S. at 323.* In other words, Dialight has met its burden of showing that its accused products do not generate regulated voltage within the meaning of claim 1 of the *'645* patent. This consequently triggers Relume's Rule 56(e) burden "to set forth specific facts showing that there is a genuine issue for trial."

Relume lists the following as evidence of Dialight's voltage regulation: 1) an advertisement and a marketing press release that state that Dialight's accused products have voltage regulation; 2) tests performed by Hochstein on Dialight's accused products that indicate they keep voltage essentially constant across the LEDs (when resistance is constant) despite input line voltage fluctuations between 80 and 135 volts a.c., (see Hochstein Reply Decl. [*809] at P 4); and 3) a statement by Relume's expert, Thomas Gafford, that Dialight's current sense resistors are also ballast resistors in that [**60] they have some ballasting effect, (see Gafford Noninfringement Decl. at PP 6-8). Relume asserts that this meager body of evidence creates a genuine issue of material fact as to whether the "converter means" of Dialight's accused products generates regulated voltage within the meaning of claim 1.

I disagree. Under the construction of claim 1 that I have adopted, Relume's evidence does not constitute proof of Dialight's literal infringement of the "generating regulated voltage" limitation because it leaves undisputed Dialight's evidence that shows its accused products have a "converter means" that is designed to regulate current. The material fact at issue here is whether Dialight's "converter means" is designed for generating regulated voltage. Even taken in a light most favorable to Relume, all that Relume's evidence demonstrates is that Dialight's marketing department thought its accused products regulated voltage, that Dialight's current-regulating "converter means" produces the same effect as a voltage-regulating "converter means" in the limited condition where Ohm's Law predicts it would, and that current sense resistors may have a mild ballasting effect because they indirectly [**61] affect voltage. None of Relume's evidence stands as direct proof that Dialight's "converter means" does not regulate current -- in other words, is not designed for the purpose of generating regulated current at its output.

Indeed, Relume and its expert admit as much. Both effectively acknowledge that Dialight's "converter means" is designed to regulate current. (See Pl.'s Consolidated Opp. at 37 & 54.) Given my construction of "generating regulated voltage," this factual concession prevents a jury from reasonably finding in favor of Relume as a matter of law. Relume has simply failed to satisfy its Rule 56(e) burden of submitting "specific facts" sufficient to show a genuine issue for trial. I therefore hold that summary judgment of literal noninfringement in favor of Dialight is appropriate with respect to claim 1 of the *'645* patent. Because dependent claims 2, 4, 5, and 6 also incorporate the "generating regulated voltage" limitation, I further hold that summary judgment of literal noninfringement in favor of Dialight is appropriate with respect to those claims as well.

2. Ecolux's Accused Product

As Dialight does, Ecolux argues that its accused product does not literally [**62] infringe claim 1 because its "converter means" generates regulated current. Ecolux had two experts testify by declaration that its power supply is designed to regulate current. The first is Mohammed Ghanem, an electrical engineer employed by Ecolux, who states in his declaration that "Ecolux uses a current regulation flyback switch mode converter and therefor [sic] does not use the same approach" as Relume's *'645* patent. (Ghanem Decl. at 2.) The second is Barry Feinberg, a retained expert, who states in his declaration that "the Ecolux power supply is

a regulated current supply or acts as a constant current supply." (Feinberg Decl. at 6.) I find that these expert declarations suffice to satisfy Ecolux's Rule 56(c) burden.

Once again, however, Relume does not dispute the fact that Ecolux's "converter means" is designed to regulate current, (see Pl.'s Consolidated Opp. at 36 & 53), but argues instead that its tests show that when resistance is constant and line input voltage varies, the voltage across the LEDs of the accused product remains essentially constant. This is the same literal infringement theory I rejected in my claim construction and in my analysis of Dialight's accused [**63] products. Accordingly, Relume has again failed to satisfy its Rule 56(e) burden of showing a genuine issue of material fact under the construction of "generating regulated voltage" I have adopted. What evidence Relume has against Ecolux's current-regulating "converter [*810] means" only pertains to whether it incidentally keeps voltage constant in the limited circumstance where Ohm's Law predicts that it would.

I therefore hold that summary judgment of literal noninfringement in favor of Ecolux is appropriate with respect to claim 1 of the *'645* patent, as well as with respect to the dependent claims, claims 2, 4, 5, and 6.

3. Precision's Accused Product

Precision also argues that its accused product does not literally infringe claim 1 of the *'645* patent because its "converter means," or interface circuit, is designed to regulate current. As supporting evidence, Precision submits declarations from two experts, Bradford Perry, an electrical engineer at Precision who designed the interface circuit, and Alex Severinsky, a retained expert, both of which establish in detail that Precision's interface circuit is designed to produce regulated current at its output. (See Perry Decl. at [**64] PP 15-20; Severinsky Decl. at PP 12-25.) Of particular note in these declarations is the observation made by both experts that Precision's interface circuit does not have a controller that performs voltage output monitoring -- in other words, it lacks an output voltage feedback loop. (See Perry Decl. at P 21; Severinsky Decl. at P 18.) Precision's expert declarations more than suffice to satisfy its Rule 56(c) burden on summary judgment.

As with Dialight and Ecolux, Relume does not dispute that Precision's "converter means" is designed to regulate current. (See Pl.'s Consolidated Opp. at 33 & 52.) The evidence Relume does offer against Precision is the same flawed body it offered against Ecolux. Thus under the construction I have adopted for the "generating regulated voltage" limitation, Relume has failed to satisfy its Rule 56(e) burden. I therefore hold that summary judgment of literal noninfringement in favor of Precision is appropriate with respect to claim 1 of the *'645* patent, as well as with respect to the dependent claims, claims 2, 4, 5, and 6.

4. Lumileds' Accused Product

Lumileds argues that its accused product does not literally infringe claim 1 because [**65] its "converter means" is designed to regulate current, not voltage. For support, it submits a declaration by its retained expert, Professor Robert Erickson, who concludes that "the power supply used in the Lumileds traffic light performs current regulation, not voltage regulation." (Fourth Erickson Decl. at P 41.) He bases this conclusion in part on his observation that "the [Lumileds] power supply does not monitor the output voltage, but instead monitors the current through the LED array." (Id.) He also observes that because the Lumileds power supply regulates current, there are no ballast resistors in the array of the accused product. (Id. at P 15-22.) Erickson's declaration satisfies Lumileds' Rule 56(c) burden.

In response, Relume fails to dispute Erickson's conclusion that Lumileds' "converter means" is designed to regulate current. As with the other three defendants, it acknowledges that Lumileds' "converter means" generates regulated current. (See Pl.'s Consolidated Opp. at 39 & 55.) The evidence it offers against Lumileds is for all purposes nearly identical to the immaterial evidence it offered against Dialight. Thus under the construction I have adopted for [**66] the "generating regulated voltage" limitation, Relume has failed to satisfy its Rule 56(e) burden. I therefore hold that summary judgment of literal noninfringement in favor of Lumileds is appropriate with respect to claim 1 of the *'645* patent, as well as with respect to the dependent claims, claims 2, 4, 5, and 6.

B. The *'909* Patent

1. Dialight's Accused Product

Dialight utilizes two different temperature compensation devices in its LED traffic signals: the "op amp" device [*811] and the "current shunt" device. Relume has asserted that both literally infringe claims 1, 2, 3, 6, 7, 9-12, 15, 16, and 18 of its *'909* patent. In its summary judgment motion, Dialight argues only that its "current shunt" device does not literally infringe Relume's asserted claims.

There is no factual dispute regarding the structure and operation of Dialight's "current shunt" device. As explained by Dialight's expert, Mr. Eikelberger, it consists of a voltage-regulating switching power supply, a variable load with a thermistor circuit, and a series-

parallel LED array. (See Eikelberger Decl. at PP 5-9.) The switching power supply supplies fixed or constant d.c. pulses to the variable load and [**67] the LED array. (See id.) If the temperature sensed by the thermistor increases, the thermistor sends a signal to the variable load to increase its impedance of the current supplied by the power supply. (See id. at PP 9-10.) As the impedance of the variable load increases, it diverts, or "shunts," more current to the LED array. (See id.) The increase in current shunted to the LED array compensates for the decrease in LED illumination due to increased temperature and thus maintains the LED array's luminous intensity. (See id.)

Dialight argues that this "current shunt" device does not literally infringe claim 1 of the *'909* patent, as well as its dependent claims 2, 3, 6, 7, and 9, because the device's switching power supply is not responsive to the luminous output signal of a sensor as required by claim 1. Dialight explains that the sensor, or thermistor, used in its device sends its luminous output signal to the variable load, not the device's switching power supply. Relume does not dispute this fact. Therefore, because Dialight's "current shunt" device lacks a power supply responsive to a luminous output signal from a sensor, I hold that a summary judgment of literal [**68] noninfringement in favor of Dialight is appropriate with respect to claims 1, 2, 3, 6, 7, and 9 of the *'909* patent.

Dialight also argues that its "current shunt" process does not literally infringe method claim 10, as well as its dependent claims 11, 12, 15, 16, and 18, because the accused process does not use an "adjustable power supply" as required by the "supplying" step of claim 10. Under the construction that I have adopted for the "adjustable power supply" limitation, Relume must establish that Dialight's accused process uses a switching power supply that is responsive to a luminous output signal from a sensor so that the ON/OFF current pulses supplied by the power supply can be adjusted in their frequency or pulse width. Relume cannot establish this, however, because it is not in dispute that Dialight's accused process uses a switching power supply that is not responsive to a luminous output signal from a sensor.

Therefore, because Dialight's "current shunt" process lacks the "adjustable power supply" limitation, I hold that summary judgment of literal noninfringement in favor of Dialight is appropriate with respect to claims 10, 11, 12, 15, 16, and 18.

2. Ecolux's Accused [69] Product**

Ecolux argues that its temperature compensation device for LED traffic signals does not literally infringe claims 1-3, 6, 7, and 9 of the *'909* patent because it lacks a sensor that senses a "condition proportional" to the luminous output of the LEDs. Ecolux's expert, Barry Feinberg, states in his declaration that because Ecolux's temperature sensor is mounted on the power supply circuit board, and not in with the LEDs, it is not in "a location to measure temperature of the LEDs in the device." (Feinberg Decl. at P 9.) He also states that "the Ecolux thermistor temperature sensor senses the temperature changes in the enclosure due to all energy sources, i.e. electrical and thermal in the form of conduction and radiation." (Id.)

As the construction I adopted for "condition proportional" made clear, the [*812] location of the sensor is irrelevant to that claim limitation. Thus as long as a sensor senses a condition that has some fixed relation with the LEDs' light output, it qualifies as the "sensor" recited in claim 1. Ecolux's evidence does not establish that its temperature sensor does not perform the sensing function of claim 1. It is possible that the ambient temperature [**70] sensed by Ecolux's sensor bears some fixed relation to the LEDs' light output. Ecolux has therefore failed to satisfy its Rule 56(c) burden. I hold that summary judgment of literal noninfringement in favor of Ecolux is not appropriate because Ecolux has not shown that a genuine issue of material fact does not exist as to whether its sensor senses a "condition proportional."

3. Lumileds' Accused Product

Lumileds argues that its accused product does not literally infringe any of the asserted claims of the *'909* patent because it does not maintain the luminous output of its LEDs at a predetermined level. As evidence, Lumileds offers a graph that shows the luminous output of its LEDs declining by 50% as the ambient temperature increases from - 40 degrees Celsius to 74 degrees Celsius (the industry's specified operating range for traffic lights). (See Fourth Erickson Decl. at P 48 & Ex. 23.)

Relume does not dispute the fact of the 50% decline. Rather, it argues that that decline must be considered essentially constant light output in light of the prior art loss of nearly 100% over the same operating range. (See Pl.'s Consolidated Opp. at 49.) This is of course the wrong [**71] comparison to be made. To establish literal infringement, Relume must compare the properly construed claims of the *'909* patent to Lumileds' accused product, not Lumileds' accused product to the prior art. See *Becton, 922 F.2d at 796*. The construction I adopted for the "maintain...at a predetermined level" limitation requires Relume to show that Lumileds' accused product keeps, or preserves from decline, the luminous output of its LEDs at an amount chosen beforehand. No jury could reasonably find that Lumileds' undisputed 50% decline in

luminous output complies with the plain meaning of this claim limitation. See *Liberty Lobby, 477 U.S. at 252.*

I therefore hold that summary judgment of literal noninfringement in favor of Lumileds is appropriate with respect to claims 1-3, 6, 7, 9-12, 15, 16, and 18 of the *'909* patent because its accused product lacks the "maintain...at a predetermined level" limitation that all those claims require.

VI. Validity

Lumileds has raised two validity challenges to Relume's *'645* and *'909* patents. With the first, Lumileds contends that certain claims of both patents are invalid because they were anticipated by [**72] prior art. With the second, Lumileds contends that all asserted claims of both patents are invalid because they would have been obvious to one of ordinary skill in the art at the time they were invented.

Federal statute requires that "each claim of a patent (whether in independent, dependent, or multiple dependent form) shall be presumed valid independently of the validity of other claims." *35 U.S.C. § 282.* "The presumption of validity under *35 U.S.C. § 282* carries with it a presumption that the examiner did his duty and knew what claims he was allowing." *Intervet America, Inc. v. Kee-Vet Lab., Inc., 887 F.2d 1050, 1054 (Fed. Cir. 1989).* In raising its validity challenges, Lumileds has the burden of showing invalidity of each claim by clear and convincing evidence. See *North American Vaccine, 7 F.3d at 1579.*

A. Anticipation

"Under *35 U.S.C. § 102,* every limitation of a claim must identically appear in a single prior art reference for it to anticipate the claim." *Gechter v. Davidson, 116 F.3d 1454, 1457 (Fed. Cir. 1997).* [*813] "There must be no difference between [**73] the claimed invention and the reference disclosure, as viewed by a person of ordinary skill in the field of the invention." *Scripps Clinic & Research Found. v. Genentech, Inc., 927 F.2d 1565, 1576 (Fed. Cir. 1991).* Anticipation is a question of fact. See *Glaxo Inc. v. Novopharm Ltd., 52 F.3d 1043, 1047 (Fed. Cir. 1995).* Thus "for summary determination to be proper, there must be no genuine dispute whether the limitations of the claimed invention are disclosed, either explicitly or inherently, by an allegedly anticipating prior art reference." *Hazani v. U.S. Int'l Trade Comm'n, 126 F.3d 1473, 1477 (Fed. Cir. 1997).*

In its response motion on the issue of obviousness, Relume alleges that I have already denied Lumileds' earlier motion for summary judgment on the issue of anticipation. This is incorrect. I reserved my ruling on Lumileds' pending anticipation motion so that, inter alia, I could efficiently decide all dispositive issues raised by the parties in one ruling.

1. The *'645* Patent

Lumileds asserts that U.S. Patent No. *5,463,280* issued October 31, 1995 to James C. Johnson ("the Johnson patent" or "Johnson") anticipates [**74] claims 1, 2, and 4 of the *'645* patent. Relume does not dispute that the Johnson patent is prior art to the *'645* patent as defined by *35 U.S.C. § 102*(a) or (e). n21 Relume did not present the prior art Johnson patent to the patent examiner when it filed its application for the *'645* patent.

n21 Section 102(a) states: "A person shall be entitled to a patent unless -- (a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent."

Section 102(e) states in pertinent part: "A person shall be entitled to a patent unless...(e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent."

Johnson teaches using LEDs to replace incandescent bulbs in illuminated signs such as exit signs. (See Johnson, 1:6-10.) Johnson discloses a variety of circuitry [**75] configurations for LED arrays and their power supplies. One such configuration -- the embodiment depicted in Figure 8 of Johnson -- teaches a simple series LED array n22 that is supplied electrical power by a rectifier and a switching power supply. Of all the configurations in the Johnson patent, this one comes closest to possessing all the limitations of claim 1 of the *'645* patent. I find, however, that it explicitly lacks one limitation found in claim 1. Specifically, while Johnson expressly teaches a switching power supply that performs power factor correction, it does not expressly state that the power supply also performs a "generating regulated voltage d.c. power" function -- a function required by claim 1 of the *'645* patent. (See Johnson, 6:67 to 7:10.) Thus the Johnson patent's switching power supply is not explicitly identical to the switching power supply of claim 1.

n22 Relume's primary argument against the anticipation of claim 1 by the Johnson patent relied on its erroneous, series-parallel

construction of "LED array." Under the construction I have adopted for that phrase, the series LED array disclosed in the Johnson patent falls within the scope of the *'645* patent's "LED array" element.

[**76]

The question then becomes whether Johnson inherently discloses a voltage-regulating switching power supply that is identical to that of claim 1. To show an inherently anticipating disclosure on summary judgment, Lumileds must clearly and convincingly establish that there is no genuine issue as to whether claim 1's voltage-regulating switching power supply is "necessarily present" in the Johnson patent and "that it would be so recognized by persons of ordinary skill." *Electro, 34 F.3d at 1052.* The undisputed evidence does establish this. Specifically, Professor Erickson has concluded that a person of [*814] ordinary skill in the art would have recognized that the MC 34261 Motorola power factor controller recommended by the Johnson patent for use in its switching power supply was "designed to be used in a voltage regulated power factor correction converter." (Third Erickson Decl. at P 17.) This is so, Erickson states, because the Motorola controller "is designed with a 'voltage feedback input'...which typically is used to monitor the output voltage for voltage regulation." (Id.) Relume does not contest Erickson's conclusion.

Accordingly, I hold that summary judgment of [**77] invalidity is appropriate because Lumileds has clearly and convincingly shown that no genuine issue of material fact exists as to the anticipation of claim 1 by the Johnson patent's identical device.

Lumileds also argues that the Johnson patent anticipates the invention of claim 2 of the *'645* patent. Claim 2 specifies that the power factor correction converter means is "a power factor correcting and voltage regulating buck/boost switchmode converter." *'645*, 13:33-36. Because the Johnson patent explicitly discloses a switchmode converter (or switching power supply), Lumileds argues that Johnson inherently discloses a buck/boost switchmode converter. I do not find, however, that the Johnson patent supports this conclusion as a matter of law. The evidence in this case establishes that a person of ordinary skill in the art would recognize that a switchmode converter has three forms: buck, boost, and buck/boost. Johnson does not disclose that any one of those forms must necessarily be associated with its switchmode converter. Thus the fact that three possible forms exist precludes the argument that any one form is necessarily present. See *Continental Can Co. USA, Inc. v. Monsanto Co., 948 F.2d 1264, 1268-69 (Fed. Cir. 1991)* [**78] (concluding that feature that "may result" from prior art configuration is not an "inherent" feature").

Accordingly, I hold that summary judgment on the issue of anticipation is inappropriate with respect to claim 2 of the *'645* patent because Lumileds has failed to present sufficient evidence showing that a buck/boost switchmode converter would be necessarily present in the Johnson device.

Finally, Lumileds contends that the Johnson patent also anticipates claim 4 of the *'645* patent. Claim 4 requires the additional element of an "electromagnetic interference filter means." *'645*, 13:43. The Johnson patent lacks an electromagnetic interference filter ("EMI filter"). Lumileds argues that it inherently discloses one because federal regulations now require EMI filters and the data sheet for the MC 34261 Motorola controller discloses using an EMI filter in combination with the controller. At best, Lumileds' evidence raises a genuine issue of material fact as to whether Johnson inherently discloses an EMI filter. The Motorola data sheet only proves that an EMI filter can be used with the Johnson device, not that it necessarily results from Johnson. As for the federal regulation, it is not [**79] clear from the section referred to by Professor Erickson, 47 C.F.R. Part 15, whether it even applies to the Johnson device, whether it was in effect at the time of the Johnson device's invention, or whether it would require an EMI for compliance.

Accordingly, I hold that summary judgment on the issue of anticipation is inappropriate as to claim 4 of the *'645* patent because Lumileds has not offered evidence sufficient to satisfy its Rule 56(c) burden.

2. The *'909* Patent

Lumileds asserts that a Japanese patent filed by Fujitsu Co., Ltd. in January 1987 and published in July 1988 as publication No. 63-178221 ("the Fujitsu publication" or "Fujitsu") anticipates claims 1-3, 7, 10-12, and 16 of the *'909* patent. Relume does not dispute that the Fujitsu publication is prior art to the *'909* patent as [*815] defined by *35 U.S.C. § 102*(b). n23 Relume did not present the prior art Fujitsu publication to the patent examiner when it filed its application for the *'909* patent.

n23 Section 102(b) states: "A person shall be entitled to a patent unless...(b)the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to

the date of the application for patent in the United States."

[**80]

The translated Fujitsu publication is entitled "Lighting Circuit for LED Array for Illumination." (Lumileds' Anticipation Mot. at Ex. 7.) It states that the object of its invention is "to provide a lighting circuit which is not affected by temperature changes and whose illumination output light is always of constant intensity and good efficiency." (Id.) The Fujitsu publication's sole claim reads as follows:

A lighting circuit for an LED array for illumination, comprising:

> LED array (1),
> temperature detection means (2) provided at this LED array (1),
> lighting control circuit (3) which inputs a temperature signal from this temperature detection means (2) and outputs a pulse signal whose duty ratio is controlled in accordance with the relevant temperature signal, and
> power source (4) connected to said LED array (1) via this lighting control circuit (3)

(Id.) Fujitsu's "lighting control circuit" regulates the electrical pulses or "signal pulses" it sends to the LED array by the use of a switch or "switching transistor T." (Id.) Fujitsu explains that the "switching transistor T has the role of turning on and off the electricity from the power source 4, which [**81] is supplied to LED array 1." (Id.) These facts about the components and operation of the Fujitsu invention are undisputed. Indeed, Relume does not, and cannot, contest that Fujitsu discloses a device that has exactly the same purpose as the device of its *'909* patent: to maintain the luminous output of LEDs at a predetermined level through the use of a sensor feedback loop and an adjustable power supply.

Relume's entire argument against the anticipation of claim 1 by Fujitsu is this: the Fujitsu device lacks a power supply that includes a switch. n24 In other words, Relume believes that the Fujitsu switch is not within the Fujitsu power supply as required by the "including" limitation of claim 1. Relume's reasoning in support of its argument: the Fujitsu "power source" is really its power supply and thus Fujitsu's switch, which is located in the lighting control circuit and not in the power source, lies outside its power supply.

> n24 This is also Relume's only argument against the anticipation of claims 2, 3, 7, 10, 11, 12, and 16 by Fujitsu.

[**82]

My analysis of Relume's argument begins with the construction I adopted for the "including" limitation of claim 1. I determined that the intrinsic evidence of the *'909* patent would lead a person of ordinary skill in the art to understand "said power supply (16) including a switching device" to mean that a switching power supply was required. As has been well established, a switching power supply must have at least two basic components: a converter, or switch, and its controller circuit. It is also well established by the totality of evidence in this case that a switching power supply's function is to take incoming electrical power from some existing power source and convert it (thus the label "converter") into whatever form of electrical power -- voltage-regulated, current-regulated, power factor corrected, etc. -- works best for the device to which it supplies power. Thus a switching power supply does not make power; rather, it transforms (modifies, regulates) already generated power according to the needs of the load it serves (in this case, an LED array).

[*816] These fundamental realities of the art make it clear that Fujitsu's lighting control circuit, not its power source, is a switching [**83] power supply in design and function. It has a switch -- the "switching transistor T" -- and it has circuitry that controls the turning on and off of that switch. It is also "responsive to said luminous output signal for adjusting the electrical energy supplied by said pulses per unit of time to adjust the average of said current passing through said LED." *'909*, 7:8-11. As Fujitsu explains:

> Temperature detection means 2 detects the temperature of LED array 1 and sends a temperature signal to lighting control circuit 3. Based on this temperature signal, lighting control circuit 3 controls the duty ratio of a constant cycle lighting pulse to the desired value, and the electricity from power source 4 is turned on and off, and LED array 1 is lighted, and the amount of light is controlled to be constant.

(Lumileds' Anticipation Mot. at Ex. 7.) Thus Fujitsu's lighting control circuit functions as a switching power supply for the particular purpose of LED temperature compensation. It takes incoming power generated

elsewhere and converts it into a form of electrical power -- here, pulses of power that vary in their width depending on the temperature sensor's input -- that better [**84] suits temperature-sensitive LEDs and therefore results in a constant level of illumination.

The only evidence Relume has that suggests the lighting control circuit of Fujitsu might not be a switching power supply is the conclusory statement of its expert, Thomas Gafford, (see Gafford Decl. at PP 17-19), and the fact that the *'909* patent just once appears to use the phrases "power source" and "power supply" synonymously, see *'909*, 5:1-3. I reject Gafford's opinion on this point because his conclusory assessment is without a reliable factual foundation n25 and because it ignores the voluminous evidence on record -- the *'645* patent, the *'909* patent, the Power Supply Cookbook, etc. -- that attests to the basic structure and identity of switching power supplies. See *Union Carbide Corp. v. American Can Co., 724 F.2d 1567, 1572 (Fed. Cir. 1984).* As to the *'909* patent's statement in question -- "switch mode supplies include any power source 16 that is turned on and off" -- I find that it actually works against Relume because the Fujitsu publication explicitly describes the lighting control circuit performing the exact same function.

> n25 In attempting to rebut Lumileds' evidence, Gafford does not conduct an analysis of the structure and function of Fujitsu's lighting control circuit and then explain how the circuit differs from the structure and function of switching power supplies as understood in the art. Gafford simply assumes from the outset that Fujitsu's "power source" is Fujitsu's power supply. The Supreme Court's recent decision in *Kumho Tire Co. v. Carmichael, 526 U.S. 137, 119 S. Ct. 1167, 143 L. Ed. 2d 238 (1999),* requires me to perform a gatekeeping role as to all proffered expert testimony. See *119 S. Ct. at 1174.* Because I find Gafford's opinion on the issue of the lighting control circuit's identity to be unreliable, I reject it pursuant to Kumho.
>
> Furthermore, it is revealing to contrast Gafford's opinion on this issue with the opinion of Lumileds' expert, Professor Erickson, who conducts a precise and cogent examination of the Fujitsu lighting control circuit and explains how one of ordinary skill in the art would recognize it as a switching power supply. (See Third Erickson Decl. at PP 40-49.) I find that this section of Professor Erickson's declaration constitutes additional clear and convincing evidence that the Fujitsu lighting control circuit is a switching power supply.

[**85]

Accordingly, I find that there is no genuine issue of material fact as to whether Fujitsu's lighting control circuit is a switching power supply as understood by those of ordinary skill in the art. The question then becomes whether Fujitsu's lighting control circuit is explicitly identical in every limitation to the "switching device" element recited by claim 1 of the *'909* patent. See *Gechter, 116 F.3d at 1457.* I find that it is. It is undisputed fact that Fujitsu's lighting control circuit has a switch or switching device, that its [*817] switching device is responsive to the feedback of a sensor that senses a condition proportional to the LEDs' luminous output, and that the switching device responds to the sensor's signal by adjusting the current pulses it supplies to the LEDs (and thus the average current in the LEDs) in order to maintain the LEDs' luminous output at a predetermined level. See *'909*, 7:7-12.

It is also undisputed fact that the Fujitsu reference explicitly discloses the three other elements of claim 1. It teaches "at least one light emitting diode," its thermistor is explicitly "a sensor...for sensing a condition proportional to said luminous output [**86] of said LED (12) and for producing a luminous output signal," and its lighting control circuit would be recognized by one of ordinary skill in the art as "a power supply (16) electrically connected to said LED (12) for supplying ON/OFF pulses of electrical energy to produce the luminous output of said LED." See *'909*, 6:66 to 7:6. Because there is "no genuine dispute" that the prior art Fujitsu publication explicitly discloses every limitation of claim 1 of the *'909* patent, and thus anticipates claim 1, I hold that summary judgment of invalidity is appropriate with respect to claim 1. *Genentech, 927 F.2d at 1576.* I also hold that summary judgment of invalidity is appropriate with respect to claim 10 because the recited method of claim 10 parallels claim 1 in its elements. n26

> n26 My claim construction of claim 10's "adjustable power supply," which determined that the phrase required a switching power supply responsive to the sensor's luminous output signal, resolves Relume's argument that Fujitsu does not disclose an "adjustable power supply." This was Relume's only argument against the anticipation of claim 10 by Fujitsu.

[**87]

Dependent claim 2 and the parallel method of dependent claim 11 recite a means, or a step, for "sensing changes in the temperature of said LED (12)." It is an undisputed fact that Fujitsu explicitly discloses a thermistor that senses the temperature of the LEDs. Accordingly, summary judgment of invalidity is appropriate with respect to the anticipation of claims 2 and 11 by Fujitsu.

Dependent claim 3 and the parallel method of dependent claim 12 require the sensing means or step to include "a predetermined temperature behavior model." It is an undisputed fact that the Fujitsu publication explicitly discloses an electronic chip pre-programmed with an LED temperature behavior model that is used in conjunction with the sensor's luminous output signal. The specification of the *'909* patent discloses the same type of chip with the same function. Accordingly, summary judgment of invalidity is appropriate with respect to the anticipation of claims 3 and 12 by Fujitsu.

Dependent claim 7 and the parallel method of dependent claim 16 require the switching device, or "adjusting" step, to adjust the electrical pulses by adjusting their width. It is an undisputed fact that Fujitsu explicitly [**88] discloses a switching device that adjusts its electrical pulses by adjusting their width. Accordingly, summary judgment of invalidity is appropriate with respect to the anticipation of claims 7 and 16 by Fujitsu.

B. Obviousness

According to *35 U.S.C. § 103*, prior art invalidates a patent for obviousness when the "subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which the subject matter pertains." See, e.g., *Richardson-Vicks, Inc. v. Upjohn Co., 122 F.3d 1476 (Fed. Cir. 1997)* (holding patent invalid for obviousness). An obviousness inquiry under section 103 ultimately presents a question of law. See *In re Donaldson Co., Inc., 16 F.3d 1189, 1192 (Fed. Cir. 1994)* (unanimous *en banc* decision). In answering that question, I must address four underlying factual considerations: [*818] (1) what is the scope and content of the prior art; (2) what are the differences, if any, between the claims at issue and the prior art; (3) what would have been the level of ordinary skill in [**89] the prior art at the time of the invention; and (4) are there any secondary considerations of non-obviousness. See *Graham v. John Deere Co., 383 U.S. 1, 17, 15 L. Ed. 2d 545, 86 S. Ct. 684 (1966).*

Lumileds argues that resolution of these four factual inquiries clearly and convincingly establishes that the remaining asserted claims of the *'645* patent -- claims 2, 4, 5, and 6 -- and the *'909* patent -- claims 6, 9, 15, and 18 -- are invalid for obviousness in light of the relevant prior art at the time of their invention. Relume argues that genuine issues of material fact exist that preclude summary judgment on the issue of obviousness.

1. The Scope and Content of the Prior Art

The Federal Circuit has repeatedly held that the scope of the relevant prior art consists of those references "reasonably pertinent to the particular problem with which the inventor was involved." *In re GPAC, Inc., 57 F.3d 1573, 1577 (Fed. Cir. 1995).* "Therefore, the prior art relevant to an obviousness determination necessarily encompasses not only the field of the inventor's endeavor but also any analogous arts." *Id. at 1577-78.* Accordingly, in determining [**90] whether a reference is from a relevant prior art, I "first must determine whether the reference is within the inventor's field of endeavor, and if it is not [I] next must determine whether the reference is reasonably pertinent to the particular problem confronting the inventor." *Id. at 1578.*

Relume believes there is a genuine dispute concerning the fields of endeavor for both of its patents. It contends that the field of the inventor's endeavor for the *'645* patent is "clearly no broader than LED array traffic signals." (Pl.'s Obviousness Opp. Mot. at 7.) Relume also contends that the field of endeavor for the *'909* patent is "safety-critical outdoor LED signals." (Id. at 8.) Relume's contentions rely on Gafford's reading of the patents. (See Gafford's Obviousness Decl. at PP 8-11).

Lumileds contends that the field of endeavor for the *'645* patent is "power supplies, power supplies for LEDs, and circuits for preventing leakage current." (Lumileds' Obviousness Mot. at 16.) Lumileds also contends that the field of endeavor for the *'909* patent is "techniques for maintaining the luminous output of an LED when temperatures rise." (Lumileds' Reply Br. at 15.) Lumileds' [**91] contentions rely on Professor Erickson's reading of the patents, (see Third Erickson Decl. at PP 8 & 41), and the deposition testimony of Hochstein, the patents' inventor.

I find no genuine dispute in the evidence regarding the *'645* patent's field of endeavor. Lumileds' understanding of the *'645*'s field fully reflects both the patent's own statement of its field and the inventor's own understanding of his field of endeavor. The *'645* patent states at its outset that its invention "relates generally to an apparatus for generating power to a light emitting diode array and, in particular, to a power supply for operating light emitting diode array traffic signals." *'645,*

1:5-8. Gafford's opinion focuses exclusively on the second half of this statement -- everything after the "in particular" -- and so he ignores the full scope of the patent's own definition of its field. Gafford's opinion also ignores the specification's unrestricted description of its invention as "an apparatus for supplying regulated voltage d.c. electrical power to an LED array." *'645*, 3:18-19. Finally, Gafford's opinion clashes with Hochstein's own identification of his field of endeavor as being a.c. powered LED [**92] arrays. n27 (See Hochstein Dep. at 163-64.)

n27 Here is the pertinent section of Hochstein's deposition:

Q Now, your patent, the *645* patent, you're saying is only limited to AC LED arrays?

A No. It's limited to what the claims say it's limited to. It's an LED array driven from the AC power line with power factor controller and voltage regulation.

Q It doesn't have to be a traffic light; correct?

A No. It has to be an AC-powered device.

Q Any AC-powered device?

A An AC-powered array of LEDs. That has voltage regulation power factor control and the dependent claims.

(Hochstein Dep. at 163-64.) Reinforcing this testimony and Lumileds' understanding of the patent's field of endeavor, the specification mentions that a.c. powered LED arrays have many "common applications" beyond traffic lights -- for instance, as "status annunciators, message boards, liquid crystal display back lights." *'645*, 1:11-17.

[*819] For all of these reasons, then, I find that Gafford's opinion on this [**93] issue is "not significantly probative" and thus fails to create a genuine issue of material fact as to the field of the inventor's endeavor for the *'645* patent. See *Liberty Lobby, 477 U.S. at 249-50*. Accordingly, I adopt the field proposed by Lumileds. I specifically find that the inventions of claims 2 and 4 are within the field of power supplies for a.c. powered LED arrays and that the inventions of claims 5 and 6 are within the field of power supplies for a.c. powered LED arrays that use circuits to prevent leakage current.

I likewise find no genuine dispute in the evidence regarding the *'909* patent's field. Lumileds' understanding of its field again enjoys the full support of the patent and its inventor. To begin with, the *'909* patent states that the technical field of its "subject invention relates to light emitting diodes" and nothing else. *'909*, 1:4-5. It describes its invention as a "circuit for maintaining the luminous intensity of a light emitting diode." *'909*, 2:7-8. The preferred embodiments mention no restriction to safety critical outdoor signals and neither do the claims. Furthermore, while the specification's background section evinces a concern for [**94] LED temperature degradation in safety-critical outdoor applications, it does not state that the invention only has significance for those applications. This makes sense given that all LEDs, regardless of whether they are used indoors or outdoors, can suffer from degradation of their luminous output due to temporarily increased operating temperatures or the passage of time. Finally, Hochstein himself was adamant that the invention of the *'909* patent, and thus his field of endeavor, involved circuits for maintaining LED luminous intensity. n28 (See Hochstein Dep. at 163.)

n28 Here is the pertinent section of Hochstein's deposition:

Q What two applications?

A What shows up in the *909* patent, has nothing to do with AC power supplies.

Q Okay. What does it have to do with?

A Maintaining luminous intensity of LEDs, period.

Q Any type of LEDs?

A That's correct. This patent has to do only with AC-powered LED arrays.

Q "This" being the *645* patent?

A The *645* patent.

(Hochstein Dep. at 163.)

[**95]

Because Gafford's opinion as to the *'909*'s field ignores these undisputed facts, I find once again that his declaration fails to demonstrate a need for trial. See *Liberty Lobby, 477 U.S. at 249-50*. Accordingly, I adopt the field proposed by Lumileds. I find that the inventions of claims 6, 9, 15, and 18 are within the field of circuits for maintaining the luminous intensity of an LED when temperature rises.

Having determined the field of the inventor's endeavors with respect to both patents, the question then becomes whether the prior art offered by Lumileds falls within those fields. As relevant prior art to the *'645* patent, Lumileds has submitted the Power Supply Cookbook, the already discussed Johnson patent, the MC 34261 Motorola power factor controller that Johnson recommends in its specification, and U.S. Patent No. *5,075,601* issued December 24, 1991 to Cleve R. Hildebrand ("the Hildebrand patent" or "Hildebrand"), [*820] which teaches the use of a dynamic load circuit to prevent leakage current from triggering conflict monitors in traffic or pedestrian signals.

The Johnson patent clearly lies within the *'645* patent's field; it states that some of its LED array [**96] embodiments can be used with a.c. power. Johnson, 2:42-43. Because Johnson is relevant prior art, so too is the MC 34261 Motorola controller it references. Likewise, the Power Supply Cookbook must also be within the *'645* patent's field because it is referred to by the *'645* patent. *'645*, 3:13-15. Finally, even though Relume disputes the exact operation and structure of the Hildebrand circuit as compared to its adaptive clamp circuit, it cannot dispute that the Hildebrand circuit functions for the purpose of eliminating leakage current problems. Hildebrand, 1:5-10. Thus Hildebrand is within the field of the inventions of claims 5 and 6. n29

n29 I note that even if Relume's proposed field of endeavor were to be accepted for the *'645* patent, the prior art offered by Lumileds would still be analogous art because each seeks to address the same problems that Hochstein addressed in the *'909* patent. See *In re GPAC, 57 F.3d at 1578*. For instance, claim 1 addresses the problems of poor power factor and varying LED illumination due to fluctuating input line voltage. So too do the Johnson patent, the Motorola controller, and the Power Supply Cookbook.

[**97]

As relevant prior art to the *'909* patent, Lumileds has offered the Fujitsu publication and two power supply textbooks -- the Power Supply Cookbook and Bernard Grob's Electronic Circuits and Applications (1982) -- both of which describe (1) various techniques for adjusting on/off pulses of energy from a switching power supply and (2) using filters to convert on/off pulses to substantially direct current ("d.c."). Fujitsu is clearly within the field of the *'909* patent; as my analysis of the anticipation issue makes clear, both circuits function for the purpose of maintaining the luminous intensity of an LED when temperature rises. Because the use of a switching power supply is necessary to accomplish that function, both power supply textbooks are also within the field of the *'909* patent. n30

n30 I note again that even if Relume's proposed field of endeavor were accepted for the *'909* patent, the prior art submitted by Lumileds would still be analogous art because each seeks to address the same problems that Hochstein sought to address in the *'909* patent. See *In re GPAC, 57 F.3d at 1578*.

[**98]

2. The Level of Ordinary Skill in the Art

I may consider a variety of factors in determining the level of ordinary skill in the art at the time of the alleged invention. See *In re GPAC, 57 F.3d at 1579*. Some of those factors include the "type of problems encountered in the art; prior art solutions to those problems; rapidity with which innovations are made; sophistication of the technology; and educational level of active workers in the field." Id. The time of invention for each asserted claim of the *'645* patent and the *'909* patent ranges between December 25, 1994 and January 31, 1996. n31 (See Hochstein Dep. at 83-84 & Dep. Ex. 9.)

n31 According to Relume's evidence, Hochstein places his date of conception of each asserted claim of the *'645* patent accordingly: claim 1 on December 25, 1994; claim 2 on January 31, 1996; claim 4 on April 18, 1995; and claim 5 and 6 also on January 31, 1996. (See Hochstein Dep. at 83-84 & Dep. Ex. 9.) Likewise, for the asserted claims of the *'909* patent, he has

placed conception at the following dates: claims 1, 9, 10, 18 on April 22, 1995; and claims 2, 3, 6, 7, 11, 12, 15, and 16 on January 31, 1996. (See id.) Lumileds has not disputed these dates.

[**99]

Lumileds' expert, Professor Erickson, states in his declaration that he "would consider the level of ordinary skill in the art as of the mid 1990's to be at least that of a senior technician with a two year associates degree in electronics and over five years of experience in power electronics or a junior engineer with an undergraduate degree in electrical engineering and at least three years of experience in power electronics." (Third Erickson Decl. at [*821] P 7.) He bases his conclusion on "interactions with people in the industry, consulting with companies, and attending industry conferences." (Id.)

Relume's expert, Mr. Gafford, believes the level of ordinary skill was lower at that time: "at most that of a bachelor's degree in electrical engineering and two to four years experience in that field [LED array traffic signals and safety critical outdoor LED signals]." (Gafford Decl. at P 13.) Gafford bases his opinion on three pieces of evidence: 1) a Dialight patent from mid-1996 that he concludes shows only rudimentary circuitry for its LED product, 2) the fact that Bradford Perry, who is a design engineer for Precision, had no experience in LED signals when he was hired by Precision, [**100] and 3) the fact that Lumileds' 30(b)(6) technical witness, Marcel Bucks, testified that the state of LED traffic light products at the beginning of 1996 was basic. (See id. at PP 14-17.)

Relume contends that the disagreement between the experts is a genuine dispute worthy of trial. I disagree. Gafford's analysis is premised on Relume's erroneously restricted view of the relevant fields of endeavor for the two patents. (See id. at PP 12-13.) Moreover, his sweeping opinion relies on anecdotal evidence. The Dialight patent, Perry's level of skill, and Buck's testimony n32 do not overcome the evident technological sophistication of the body of relevant prior art on record: that is, the Power Supply Cookbook, n33 the Johnson patent, the Hildebrand patent, the Fujitsu publication, and the prior art cited in the *'645* and *'909* patents. See *In re GPAC, 57 F.3d at 1579* (noting that review of prior art references provides "valuable insight" into level of skill in the art).

n32 Bucks did not testify that the level of ordinary skill in the art was basic in 1996 but only that those products he tested at that time were basic in design because there were no industry specifications requiring anything more. (See Bucks Dep. at 52-54.) He also testified that Philips and Hewlett-Packard were already working on an advanced LED power supply at that time. (See Bucks Dep. at 54-55, 303-05.) [**101]

n33 Notably, the Power Supply Cookbook, which was published in 1994, states in its introduction that switching power supplies are "complicated to design" and "unfamiliar to the typical design engineer." Id. at 25.

Indeed, I find the range of relevant prior art to be dispositive as to the question of ordinary skill. It shows that in the fields of both patents, a person of ordinary skill would need to understand not only the design issues associated with LEDs -- their sensitivity to temperature and/or input voltage fluctuations, their degradation over time, etc. -- but also the design issues associated with switching power supplies -- electromagnetic interference, the pros and cons of voltage v. current regulation, power factor correction, etc. Lumileds' proposed level of skill is consistent with the breadth of knowledge required by the inventions of the *'645* and the *'909* patents.

Even if the lesser level of skill offered by Relume were found to have sufficient support in the evidence to create a factual dispute, Relume has not shown that this dispute would have a material bearing on the [**102] non-obviousness inquiry before me. There has been no evidence entered that suggests that Relume's lesser level of skill would preclude a person of ordinary skill in the art from recognizing that the relevant prior art submitted by Lumileds made the asserted claims obvious at the time of their invention.

Accordingly, I find that no genuine issue of material fact exists as to the ordinary level of skill at the time of the invention of the *'645* and *'909* patents. The evidence clearly and convincingly supports the level of skill proposed by Lumileds. Relume has offered only a "scintilla of evidence" for its position. *Liberty Lobby, 477 U.S. at 252.*

3. Differences, If Any, Between the Invention and the Prior Art

a. Claims 2 and 4 of the *'645* Patent

Lumileds contends that there is no meaningful difference for obviousness purposes [*822] between the Johnson patent and claim 2 of the *'645* patent. As stated

before, claim 2 requires that the *'645* patent's power factor correction converter means be a buck/boost switchmode converter. The Johnson patent explicitly discloses a switchmode converter but does not specify its type, i.e. whether it is a buck., boost, or buck/boost [**103] converter. Professor Erickson has testified that it would have been obvious to one of ordinary skill to use a buck/boost converter with the Johnson device because the Power Supply Cookbook explained how to implement such a circuit for switching power supplies. (See Third Erickson Decl. at P 20.) He explains that "even a skilled technician would know to select a buck/boost converter if the input voltage could be either higher or lower than the desired output voltage." (Id. at P 19.)

Relume has only two arguments in response. First, the Johnson patent does not disclose a device with the LED array required by claim 1 because its Figure 8 embodiment lacks a series-parallel configuration. My claim construction of "LED array" has eliminated this argument. The second argument, then, is Relume's only remaining argument against a finding of obviousness as to claim 2. That argument is this: even if left unrebutted, Professor Erickson's third declaration does not establish obviousness because 1) he "never even states that the asserted claims would have been obvious at the time of the invention"; and 2) he generally fails to state the motivation for combining relevant prior art. [**104] (Pl.'s Obviousness Opp. Mot. at 23-24.)

The first criticism is baseless. With respect to his third declaration, Professor Erickson states in his third supplemental declaration that "all of my opinions concerning obviousness were made from the point of view of a person of ordinary skill in the art as of the time of the inventions of the *'645* and *'909* patents, that is, as of the mid 1990's." (Third Suppl. Erickson Decl. at P 61.)

The second criticism is likewise baseless. Professor Erickson is careful throughout both of his obviousness declarations to explain what motivation, suggestion, or incentive in the relevant prior art would have made a combination obvious to one of ordinary skill in the art at the time of the invention at issue. In fact, Relume's criticism reveals a flaw in its own strategy in defending against Lumileds' obviousness challenges. Relume would have me treat the obviousness test with the stringency of an anticipation test, permitting no combinations to ever invalidate an invention as obvious simply because they are combinations.

In this vein, Relume accuses Professor Erickson of repeatedly using only the level of knowledge of one of ordinary skill in the art to [**105] supply missing suggestions to combine. Relume believes his declaration offends *Al-Site, supra,* in which the Federal Circuit reaffirmed the fundamental principle that skill in the art will rarely operate to supply missing knowledge or prior art to reach an obviousness judgment. See *174 F.3d at 1324.* As the court further explained, "skill in the art does not act as a bridge over gaps in substantive presentation of an obviousness case, but instead supplies the primary guarantee of objectivity in the process." Id.

While I of course heed the warning of Al-Site, I nevertheless find that its concern is inapplicable to the facts of this case. First of all, nearly all of the prior art at issue in Al-Site had been presented to the patent examiner by the patentee; the Federal Circuit observed that this made the obviousness burden more difficult to overcome. See *id. at 1323-24.* Here, in contrast, some of the most important prior art was not before the patent examiner, as indicated by my anticipation holdings. Thus Lumileds' burden is more easily overcome. See *Para-Ordnance Mfg. Inc. v. SGS Importers Int'l Inc., 73 F.3d 1085, 1088-89 (Fed. Cir. 1995),* [**106] cert. denied, *519 U.S. 822, 136 L. Ed. 2d 38, 117 S. Ct. 80 (1996).* Second, it is important [*823] to note that Al-Site's caution does not apply when the prior art references themselves provide some explicit or implicit motivation, suggestion, or incentive for combination. See *Al-Site, 174 F.3d at 1324.* As will become clear, the prior art references at issue in this case provide their own suggestions and incentives for combination. And, third, the court in Al-Site noted that the evidence against the asserted combination was substantial. See id. That is not the case here.

The first good example of the inapplicability of Al-Site is Lumileds' obviousness challenge to claim 2 of the *'645* patent. The interesting fact about the Johnson patent, and why it is so damaging to the validity of Relume's *'645* patent, is that it is itself already a combination. It wed the art of power supply electronics -- in particular, the art of switching power supplies (as explained in the Power Supply Cookbook) -- to the art of retrofit LED arrays for the benefit of efficient, long-lasting illumination. This is undisputed (and also why Johnson anticipates claim [**107] 1). Also undisputed is the fact that inherent in the use of switching power supplies at that time was the knowledge that only three configurations existed: buck, boost, and buck/boost. Thus by teaching a switching power supply, the Johnson patent would have implicitly suggested to one of ordinary skill in the art the possibility of using a buck/boost switchmode converter for its power supply. This is all that Professor Erickson's opinion seeks to explain. Thus I find his unrebutted opinion regarding claim 2 to be clear and convincing evidence of the obviousness of that claim. I also find the relevant prior art references -- the

Johnson patent and the Power Supply Cookbook in particular -- to be clear and convincing evidence, on their own, of the obviousness of claim 2.

Lumileds also argues that there is no difference for obviousness purposes between claim 4 of the '645 patent and the Johnson patent. Claim 4 recites the additional limitation of an EMI filter. Relume again has the same two flawed arguments in response. It does not submit evidence to rebut the evidence of the prior art references or Professor Erickson's opinion. Erickson concludes that the Johnson patent would have [**108] made the invention of claim 4 obvious to one of ordinary skill in the art because, among other things, the data sheet for the MC 34261 Motorola controller recommended by Johnson describes using an EMI filter. (See Third Erickson Decl. at PP 21-25.) Erickson points out that "every power supply circuit shown in the data sheet with the MC 34261 includes an EMI filter." (Id. at P 23.) Erickson also notes that the Power Supply Cookbook taught the crucial nature of EMI filters for switching power supplies; so it states that "the EMI filter is an integral part of any PFC [power factor correction] circuit." (Id. at P 22.)

I find all of this undisputed evidence to be clear and convincing evidence of the obviousness of claim 4 in light of Johnson and the Motorola data sheet. By recommending the use of the MC 34261 Motorola controller in its switching power supply, the Johnson patent implicitly suggests to one of ordinary skill in the art that the information in the controller's data sheet is useful and suitable for the operation of its invention. That information includes a strong teaching to use EMI filters with switching power supplies. Thus I find the Johnson patent is [**109] no different than the invention of claim 4 for purposes of obviousness because it suggests a combination of its explicit teachings -- the rectifier, the power factor correcting switching power supply, and the LED array -- with the EMI filter teaching of the Motorola data sheet.

b. Claims 5 and 6 of the *'645* Patent

Lumileds argues that the prior art Hildebrand patent's dynamic load circuit is identical, or at least equivalent, to the adaptive clamp circuit of claims 5 and 6. The Hildebrand circuit is directed to "attenuating the effects of leakage currents when a particular [traffic or pedestrian [*824] crossing] signal is switched to its off state." Hildebrand, 1:8-10. It is undisputed fact that the Hildebrand circuit uses a Zener diode (CR5) in combination with a transistor (Q2) and that those components correspond to the Zener diode (D5) and the transistor (Q1) of the *'645* clamp circuit's "voltage sensing means." Hildebrand, 5:57-65. It is also undisputed fact that the Hildebrand circuit uses a transistor (Q3) in combination with a resistor (R7) and that those components correspond to the transistor (Q2) and the resistor (R5) of the *'645* clamp circuit's "control load means." Hildebrand, [**110] 5:66 to 6:6. Finally, it is undisputed fact that the Hildebrand circuit places resistor (R7) of its "control load means" in the circuit when the traffic light is off, thereby preventing leakage current, and that it completely removes this resistor (R7) from the circuit when the light is on. Hildebrand, 6:17-52. This operation corresponds to that of the *'645* clamp circuit, which places the resistor (R5) of its "control load means" in the circuit when the light is off and then completely removes that resistor (R5) from the circuit when the light is on. *'645*, 7:53 to 8:1.

This undisputed evidence suffices to show that the Hildebrand device is nearly identical in structure and function to the adaptive clamp circuit of claims 5 and 6. First of all, it shows that the Hildebrand device "clamps" within the meaning of the *'645* patent. n34 That is, when voltage falls below a certain amount -- the zener voltage of Hildebrand's Zener diode (CR5) -- that diode does not conduct and the leakage current is directed through resistor (R7). Hildebrand, 6:23. Likewise, when the *'645*'s voltage falls below a certain amount -- the zener voltage of its Zener diode (D5) -- that diode does not conduct and [**111] leakage current is directed through resistor (R5). *'645*, 7:59-62. Second, the undisputed evidence also shows that the Hildebrand device is "adaptive" within the meaning of the *'645* patent. When the Hildebrand light is on, its dynamic load circuit removes the resistor (R7), and when its light is off, it places the resistor (R7) in the circuit to clamp leakage. Hildebrand, 6:42-50; (Third Erickson Decl. at PP 33-34).

> n34 Relume argues that Hildebrand does not "clamp" within the meaning of the *'645* patent because it does not do so at the zener voltage threshold of 40 volts -- an amount the *'645* specification mentions (but does not require). I do not find this to be a substantial difference for obviousness purposes, however, because the specification statements in question do not suggest that the function of clamping cannot occur at different zener voltage thresholds.

In response to this overwhelming evidence of similarity, Relume first argues that the Hildebrand dynamic load circuit substantially differs from *'645*'s [**112] adaptive clamp circuit because the Hildebrand transistor Q3 is not a solid state switch, as required by the *'645* patent, but instead is a linear amplifier. Relume's

argument relies on the opinion of its expert, Mr. Gafford. I do not find that its argument precludes summary judgment, however. Hildebrand does not call the transistor Q3 a "linear amplifier." Gafford bases his opinion solely on his conclusory observation that some of the language of the Hildebrand patent is "unique to the language of amplifiers." (Gafford Decl. at P 28.) Gafford does not explain how or why this is so.

Throwing further doubt on Gafford's reliability, Lumileds offers evidence showing that all switches, including Hildebrand's, operate in a linear amplifier mode for a period of milliseconds as they switch between on and off -- yet those in the art still consider them to be switches. (See Third Suppl. Erickson Decl. at P 63.) Thus I find that Gafford's opinion fails to set forth specific facts sufficient to raise a genuine issue of material fact. See *Lockwood v. American Airlines, Inc., 107 F.3d 1565, 1571 (Fed. Cir. 1997)* (finding that expert's conclusion that prior art patent claimed [**113] a limited structure did not preclude summary [*825] judgment when the patent's written description appeared to contradict his conclusion).

Relume's second argument in the face of Lumileds' evidence of structural and functional similarity is that the combination of Hildebrand's circuit and the Johnson device would be inefficient, thereby rebutting any motivation for combination. Relume's inefficiency argument relies on tests performed by Hochstein on a dynamic load circuit he built to match that taught in Hildebrand. Hochstein found that the circuit's power factor, harmonic distortion, and power dissipation characteristics would not pass ITE or Caltrans specifications for LED traffic signals. (See Hochstein Reply Decl. at PP 14-16.)

Even viewed in a light most favorable to Relume, Hochstein's tests do not constitute evidence that shows that the Hildebrand and Johnson devices are inefficient when operated *together*. All Hochstein's tests establish is the unsurprising fact that the Hildebrand device *alone* would not win the approval of industry specifications that apply to an entire power factor corrected, voltage-regulated LED power supply. The relevant tests for obviousness purposes [**114] would have been to test and compare the performance of Hildebrand's circuit against that of the *'645*'s adaptive clamp circuit or, even better, to test and compare the performance of a combined Hildebrand and Johnson device against that of the entire invention of claims 5 or 6. Relume does not submit evidence of either.

Moreover, Lumileds is correct to point out that the claims of the *'645* patent do not recite any values for power factor, harmonic distortion, or power dissipation. As the Federal Circuit has stated "the name of the game is the claim." *In re Hiniker, Co., 150 F.3d 1362, 1369 (Fed. Cir. 1998)* (upholding rejection for obviousness even though prior art performed less efficiently than patent's device because it refused to read specification's operational characteristics into broader claims). Accordingly, even if the efficiency of the Hildebrand circuit were to be less than that of the *'645*'s adaptive clamp circuit (or the efficiency of Hildebrand/Johnson were less than that of claim 5 or 6), it would be irrelevant to the obviousness question before me.

This is particularly true in this case because a person of ordinary skill in the art would have had a strong [**115] motivation to combine Hildebrand and Johnson at the time of claim 5 and 6's invention. Hildebrand teaches the crucial lesson that retrofit bulbs in safety critical traffic or pedestrian crossing signals will create leakage current problems that could interfere with the conflict monitors. Hildebrand, 1:6-41. Thus Hildebrand would have motivated a person of ordinary skill in the art to combine its dynamic load circuit with the retrofit lamp of Johnson in order to prevent these well-known leakage current problems.

Accordingly, I find that the combination of the prior art Hildebrand and Johnson patents constitutes clear and convincing evidence of the obviousness of claims 5 and 6 of the *'645* patent at the time of their invention. Relume's insufficient evidence fails to demonstrate a need for trial on the factual issue of the structural and functional similarity of a combined Hildebrand/Johnson device to claims 5 and 6. See *Liberty Lobby, 477 U.S. at 249-50.*

c. Claims 6 and 15 of the *'909* Patent

Lumileds argues that a prior art combination -- the Fujitsu publication with one or both power supply textbooks -- is identical to claims 6 and 15 of the *'909* patent. Claims [**116] 6 and 15 recite the alternate technique for adjusting the energy supplied to the LEDs by frequency modulation (instead of pulse width modulation). Fujitsu discloses pulse width modulation, but not frequency modulation. Both the Power Supply Cookbook and the Electronic Circuits and Applications disclose the use of frequency modulation with switching [*826] power supplies. Based on these sources and his expertise, Professor Erickson states in his declaration that the two methods were well-known design choices within the field of switching powers supplies. (See Third Erickson Decl. at PP 50-53.) Indeed, the *'909* patent concedes this fact of the prior art when it notes that it is "widely recognized that control of power supply output voltage or output current is most efficiently accomplished by varying the pulse width or frequency of the switched waveform." *'909*, 5:51-54. From this evidence, then, it is

clear that the Fujitsu publication would have suggested the alternate use of frequency modulation to one of ordinary skill simply because it used a switching power supply to adjust the average current to the LEDs.

Relume provides no specific facts in response. It reiterates conclusory [**117] denials that it also raised in the anticipation inquiry. Pursuant to Rule 56(e), this does not suffice to create a genuine dispute worthy of trial. I therefore find that the Fujitsu publication in combination with either power supply textbook constitutes clear and convincing evidence of obviousness because the combinations are no different from the inventions of claims 6 and 15.

d. Claims 9 and 18 of the *'909* Patent

Lumileds argues that a prior art combination -- the Fujitsu publication with the Power Supply Cookbook -- is identical to the inventions of claims 9 and 18 of the *'909* patent. Claims 9 and 18 relate to using a filter to provide substantially d.c. power to the LEDs. The Power Supply Cookbook establishes that it was well known in the art of the mid-1990's that a filter could be used to convert on/off pulses from a switching power supply to substantially d.c. power. The *'909* patent acknowledges that d.c. power supplies "normally" use a filter to produce substantially d.c. power. *'909*, 4:54-56. And it is undisputed that the Fujitsu lighting control circuit is a d.c. power supply of the type referred to in the *'909* patent. (See Third Suppl. Erickson Decl. [**118] at P 68.) Thus the evidence offered by Lumileds more than satisfies its Rule 56(c) burden of showing that there is no genuine issue of material fact that a combination of the Fujitsu publication and the Power Supply Cookbook is clear and convincing evidence of the obviousness of claims 9 and 18 at the time of their invention.

Relume's only defense is that Fujitsu teaches away from using a filter. Specifically, Relume argues that the Fujitsu circuit would not use a filter because it is well known in the optical scanning arts that the detector circuit must receive pulsed light from the LEDs for its efficient operation -- not the substantially constant light that would come from filtered, substantially d.c. power. Relume's only evidence in support of this argument comes from its inventor, Mr. Hochstein. (See Hochstein Reply Decl. at P 9.)

I find that Relume's argument fails to create a genuine issue of material fact. It depends on an erroneously narrow view of the invention disclosed by the Fujitsu publication. Although Fujitsu mentions application of its invention in the field of optical scanning devices, its claim language and written description are broad in scope and reveal [**119] an invention that could have application in any setting where LEDs are exposed to increasing temperatures. Furthermore, Fujitsu nowhere discloses the use of a pulse detector with its circuit. Nor does Relume submit any prior art references that support Hochstein's assertion about the ordinary knowledge of those in the optical scanning arts.

The Fujitsu publication simply lacks any express or implied teaching away from the use of a filter to produce substantially d.c. power. In fact, the evidence offered by Lumileds establishes that the Fujitsu publication would have suggested the use of a filter to one of ordinary skill given the fact that it is a d.c. powered device. I therefore find that the combination of Fujitsu and the Power Supply Cookbook constitutes clear and convincing evidence of obviousness [*827] because there is no difference between the combined prior art and the inventions of claims 9 and 18.

4. Secondary Considerations

This final Graham inquiry requires me to consider relevant evidence of any secondary, non-obviousness factors such as commercial success, long-felt need, failure of others, skepticism and unexpected results. See *3 M v. Johnson & Johnson Orthopaedics, Inc., 976 F.2d 1559, 1573 (Fed. Cir. 1992).* [**120] These secondary considerations, however, "are but a part of the 'totality of the evidence' that is used to reach the ultimate conclusion of obviousness." *Richardson-Vicks, 122 F.3d at 1483.* The existence of such evidence does not control the obviousness determination. Id.; see also *Ryko Mfg. Co. v. Nu-Star, Inc., 950 F.2d 714, 719 (Fed. Cir. 1991)* (noting that the weight of secondary considerations may be of insufficient weight to override a determination of obviousness based on primary considerations).

Relume makes various assertions and submits a smattering of anecdotal evidence as to four secondary considerations: copying, commercial success, long-felt need, and failure of others or skepticism. Each hinges on Relume's unstated assumption that all LED traffic lights which meet industry specifications must infringe the *'645* and *'909* patents. As defendants' successful motions for noninfringement have demonstrated, however, there are many ways to satisfy industry specifications without using literally infringing technology. Even Hochstein concedes this. (See Hochstein Dep. at 455-56.)

I find Relume's arguments as to the copying factor to be without [**121] evidentiary support. Except for Ecolux's temperature compensation circuit, I found that all the accused products at issue in the motions did not literally infringe the asserted claims of the *'645* and *'909* patents. Furthermore, Relume has no independent

evidence of copying, only the assertion that because defendants at one point argued an equitable estoppel defense, they admit they copied Relume's patents. This assertion is of course insufficient to preclude summary judgment in the face of defendants' strong prima facie evidence of obviousness.

The commercial success factor is likewise unhelpful for Relume. Relume argues that evidence of defendants' commercial success, as well as its own, is evidence of the non-obviousness of its patents. This argument fails for two simple reasons. First, because Relume has failed to defeat defendants' motions for non-infringement (except with respect to Ecolux and the *'909* patent), it cannot rely on the well-substantiated success of defendants' accused products to prove the commercial success of its claimed features. Second, Relume has not shown that its claimed features have enjoyed any commercial success. All it has proved to date is that one community [**122] -- Murietta, California -- has awarded it a bid for 400 LED traffic signals.

As to long-felt need, the only evidence Relume offers is evidence of a need for industry specifications, not necessarily for the claimed features of Relume's patents. Because defendants have demonstrated that there are several ways manufacturers can meet those specifications, Relume cannot rely on those specifications to establish that there was a long-felt need for its patents. At best, Relume's evidence suggests that the LED traffic signal industry began in the last few years to regulate itself.

The final factor Relume argues is failure of others or skepticism. Its evidence of this is slim to non-existent. It first offers the testimony of Patrick Mullins, an individual associated with McCain Traffic Supply, as evidence of failure. (See Mullins Dep. at 40-41, 80.) Relume claims that he testifies as to McCain's inability to make an LED traffic signal with power factor correction. A close reading of Mullins' testimony, however, reveals that he only states that McCain never successfully marketed an [*828] LED traffic signal with power factor correction, not that it could not build one. (See id. at 80.) Relume [**123] also offers the testimony of a Martin Wallen as evidence of skepticism as to the *'909* patent. Wallen's testimony alone does not constitute sufficient evidence to overcome the strong prima facie evidence of obviousness in this case.

In the end, Relume cannot point to any convincing evidence of non-obviousness. In light of the clear and convincing prima facie evidence of obviousness in the prior art, I therefore hold that claims 2, 4, 5, and 6 of the *'645* patent and claims 6, 9, 15, and 18 of the *'909* patent are invalid because they would have been obvious to one of ordinary skill in the art at the time of their invention.

Conclusion

For all of the foregoing reasons, Dialight's, Precision's, and Lumileds' motions for noninfringement are **GRANTED** on the issue of literal noninfringement as to all asserted claims of the *'645* and *'909* patents. Ecolux's motion for noninfringement is **GRANTED** on the issue of literal noninfringement as to all asserted claims of the *'645* patent, but is **DENIED** on the same issue as to the asserted claims of the *'909* patent.

I decline to consider the issue of infringement through the doctrine of equivalents at this time because of the [**124] parties' inadequate briefing on that issue. This has no bearing on the outcome of the case, however, because of my validity rulings, which find all asserted claims invalid due to prior art.

Accordingly, Lumileds' anticipation motion is **GRANTED** as to claim 1 of the *'645* patent and claims 1-3, 7, 10-12, and 16 of the *'909* patent, but is **DENIED** as to claims 2 and 4 of the *'645* patent. Lumileds' obviousness motion is **GRANTED** as to claims 2, 4, 5, and 6 of the *'645* patent and claims 6, 9, 15, and 18 of the *'909* patent.

IT IS SO ORDERED.

John Feikens

United States District Judge

DATED: Aug 26, 1999

RELUME CORPORATION, Plaintiff-Appellant, v. DIALIGHT CORPORATION, ECOLUX, INC., and PRECISION SOLAR CONTROLS, INC., Defendants, and LUMILEDS LIGHTING BV, PHILIPS LIGHTING BV, and HEWLETT-PACKARD COMPANY, Defendants-Cross Appellants.

00-1164, 00-1180

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

4 Fed. Appx. 893; 2001 U.S. App. LEXIS 2045

February 8, 2001, Decided

NOTICE: [**1] RULES OF THE FEDERAL CIRCUIT COURT OF APPEALS MAY LIMIT CITATION TO UNPUBLISHED OPINIONS. PLEASE REFER TO THE RULES OF THE UNITED STATES COURT OF APPEALS FOR THIS CIRCUIT.

SUBSEQUENT HISTORY: Rehearing Denied March 6, 2001, Reported at: *2001 U.S. App. LEXIS 4466.*

DISPOSITION: Affirmed.

JUDGES: Before CLEVENGER, SCHALL, and BRYSON, Circuit Judges.

OPINIONBY: CLEVENGER

OPINION: [*894]

CLEVENGER, Circuit Judge.

Relume Corporation ("Relume") appeals from the summary judgment of the United States District Court for the Eastern District of Michigan, holding that the defendants' accused products do not literally infringe the asserted claims of U.S. Patent No. *5,661,645* ("the *'645* patent") or U.S. Patent No. *5,783,909* ("the *'909* patent"), both assigned to Relume, and holding that both patents are invalid. *Relume Corp. v. Dialight Corp., 63 F. Supp. 2d 788, 802 (E.D. Mich. 1999).* We affirm.

I

Relume raises several arguments on appeal: (1) whether the district court erred in its interpretation of certain limitations in the patents, (2) whether such errors in claim interpretation led to errors in the court's analysis of the validity issues, (3) whether disputed issues of material fact preclude summary judgment on the validity issues, and (4) whether alleged errors in claim interpretation [**2] or the disputed issues of material fact undercut the district court's judgment of no literal infringement.

II

We have fully reviewed the careful, extensive and well-crafted opinion of the district court. We have carefully examined the arguments presented by the parties in their briefs and have considered in full the arguments made by the parties at oral argument.

For the reasons stated in the opinion of the district court, we agree that all of the asserted claims of the *'645* and *'909* patents are invalid. Because we affirm the district court's judgment on the validity issues, we need not reach the questions raised by Relume as to the judgment of noninfringement.

1 of 3 DOCUMENTS

RELUME CORPORATION, Plaintiff-Appellant, v. DIALIGHT CORPORATION, ECOLUX, INC., and PRECISION SOLAR CONTROLS, INC., Defendants, and LUMILEDS LIGHTING BV, PHILIPS LIGHTING BV, and HEWLETT-PACKARD COMPANY, Defendants-Cross Appellants.

00-1164, 00-1180

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

2001 U.S. App. LEXIS 4466

March 6, 2001, Decided
March 6, 2001, Filed

NOTICE: [*1] DECISION WITHOUT PUBLISHED OPINION

PRIOR HISTORY: Original Opinion of February 8, 2001, Reported at: *2001 U.S. App. LEXIS 2045.*

JUDGES: Before CLEVENGER, Circuit Judge, SCHALL, Circuit Judge, and BRYSON, Circuit Judge.

OPINION:

ORDER

A petition for rehearing having been filed by the APPELLANT,

UPON CONSIDERATION THEREOF, it is

ORDERED that the petition for rehearing be, and the same hereby is, DENIED.

The mandate of the court will issue on March 13, 2001.

Dated: March 6, 2001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Peter A. Hochstein	)	
Patentee: Relume Corporation	)	Group Art Unit: 2838
Patent No.: 5,661,645	)	
Filed: June 27, 1996	)	Examiner: B. Vu
Issued: August 26, 1997	)	
Serial No.: 09/382,702	)	Docket No. 65.016-046
Reissue Filed: August 24, 1999	)	
For: POWER SUPPLY FOR LIGHT EMITTING DIODE ARRAY	)	

RESPONSE TO OFFICE ACTION DATED JANUARY 15, 2003

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Dear Sir:

The two most frustrating experiences an applicant may have with the Patent Office are (1) to wait for an extraordinary length of time to receive an action on the merits, and (2) to receive a rejection of claims previously allowed, over art that has always been of record. We experienced both with the January 15, 2003 office action. Before we explain why each of the rejections should be withdrawn and the patent allowed to re-issue, we recap certain events in the timeline.

We filed this reissue application on August 24, 1999. On September 7, 2000, the Examiner allowed the claims now under rejection. Then in February 2001, the Federal Circuit affirmed the invalidity judgement of claims 1, 2, 4, 5 and 6. Because of this, on February 28, 2001, we filed a Petition to Withdraw from Issue, and on March 5, 2001, a

Request for Continued Examination. The Petition was granted on March 21, 2001.

As of the commencement of the continued examination in early 2001, the claims under examination were *different from* the claims that had been invalidated and were no longer being pursued. That is, claims 1, 2, 4, 5 and 6 are not in this reissue application and not subject to examination hereunder. *Each* of the remaining claims contained additional, narrowing limitations that took them outside the scope of the court decision directed to claims 1, 2, 4, 5 and 6.

In the almost two year span between March 5, 2001 and January 15, 2003, we repeatedly telephoned Examiner Vu and Special Programs Examiner Glick. Right or wrong, we received the impression, at least from Examiner Vu, that the claims would be re-allowed after such continued examination, and that an action on the merits would be forthcoming. Meanwhile, in this 22 month period, we submitted some additional papers for consideration as potentially relevant to the examination. We received feedback that such papers were helpful.

The January 15, 2003 office action was quite unexpected. It contains new grounds for rejecting claims 24-35, 37, 38 and 40-44. These grounds are based on art that has always been of record. In addition, all claims (3, 7-35, 37, 38 and 40-45) stand rejected based on a defective reissue oath. This "defect" is apparently that the application claim which is designed to correct the stated "reissue error" (claim 44) right now stands rejected.

We disagree with and traverse all rejections, as follows. As explained in detail with respect to each rejected claim, the Examiner has either failed to appreciate narrowing limitations in the claims which are completely absent from the prior art, or has used hindsight

to apply the teachings of the inventor against him in urging that certain combinations would have been obvious.

We draw particular attention to the patentability of claims 40 and 44, discussed below. These claims so clearly call out structural and functional limitations found nowhere in the prior art (Hildebrand or elsewhere), that their patentability should not reasonably be subject to debate.

CLAIM 24

TEXT OF CLAIM:

24. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and having a power supply output;

a plurality of LEDs coupled to the power supply output and having multiple current paths for dissipating power and emitting light;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION:

The Examiner states that this claim is unpatentable for obviousness over Johnson, U.S. Patent No. 5,463,280, in view of the Power Supply Cookbook and the Motorola data sheet for the MC34261 controller in view of Applicant's Prior Art (APA) and in view of Hildebrand, United States Patent No. 5,075,601. The Examiner states this five-reference combination teaches the whole claim.

With respect to placement of multiple LED current paths with a switching power supply into an outdoor LED signal, the Examiner states the "Applicant's Prior Art (APA) in view of Hildebrand discloses that ***it is known*** in the art to make use of series-parallel LED array ***in a switching power supply*** and for their use ***in traffic, pedestrian or rail crossing signal housing***." (Emphasis added).

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN:

The Examiner misapprehends the admitted prior art shown in the '645 patent, Figs. 1-3 (the "APA"), as well as the Hildebrand disclosure. Nowhere does the art show "it is known" to use a switching power supply with a series-parallel LED array in a traffic, pedestrian or rail crossing signal. That teaching is provided exclusively by the inventor, in his '645 patent which is the subject of this reissue application. For instance, directly contrary to the Examiner's stated understanding, Figs. 1-3 of the APA show power supplies for series-parallel LED arrays, but they show outdoor signals that ***lack any switching whatsoever***. As for Hildebrand, it discloses a pedestrian / traffic signal, but only for a "luminescent tubular lamps," which are fluorescent or neon. ('601 Patent, 1:11-14, 1:20, 1:28, 4:50-53, 6:67).

Thus, Hildebrand ***lacks any LEDs whatsoever***. The only motivation to combine series-parallel LEDs and switching power supplies in a traffic, pedestrian or rail crossing signal comes from Peter Hochstein himself in his '645 patent.

The Examiner seems to have addressed the non-relevant question of whether it would have been obvious to place a series-parallel LED array into an outdoor signal. Thus the Examiner mentions that "use of these LED arrays provides a greater benefit . . . highly desirable for their use in traffic, pedestrian or rail crossing signals housing." This analysis drops the switching power supply out of consideration. Whether or not it would have been obvious to use series-parallel LED arrays in an outdoor signal, the Examiner has not shown or attempted to show it would have been obvious to place a series-parallel LED array ***driven by a switching power supply*** into an outdoor signal.

Note that the "traffic, pedestrian or rail crossing signal housing" limitation was not part of any of claims 1, 2, 4, 5 or 6 invalidated by the court.

Since the Examiner's stated reasons for rejecting claim 24 are clearly incorrect, claim 24 is patentable over the art of record and should be allowed.

CLAIM 25

TEXT OF CLAIM:

25. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and having a power supply output;

a plurality of LEDs coupled to the output of the power supply in at least two current paths, whereby the cessation of current through one current path due to single point failure does not prevent current flow through another current path;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claim 24, above.

<u>CLAIM 26</u>

TEXT OF CLAIM:

26. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply

input coupled to the rectifier output and having a power supply output;

an LED array having an input connected to the output of the power supply;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claim 24, above. Note that the "LED array" in this case need not be one that provides for multiple current paths.

CLAIM 27

TEXT OF CLAIM:

27. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and having a power supply output;

a plurality of LEDs electrically configured such that the failure of a single

LED results in continued emission of light from a substantial number of the rest of the plurality of LEDs;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claim 24, above.

<u>CLAIM 28</u>

TEXT OF CLAIM:

28. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage;

a plurality of LEDs coupled to the power supply output and having multiple

current paths for dissipating power and emitting light;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claim 24, above.

As an additional basis for patentability, the Examiner has not pointed to, or attempted to point to, any motivation in the prior art to combine a ***traffic, rail or pedestrian outdoor signal*** with a power supply which "maintain[s] current and voltage waveforms substantially in phase and [] provid[es] a regulated current output with respect to variations in the input line voltage." Peter Hochstein is the source of this teaching, not the prior art.

<u>CLAIM 29</u>

TEXT OF CLAIM:

29. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage;

a plurality of LEDs electrically configured such that the failure of a single LED results in continued emission of light from a substantial number of the rest of the plurality of LEDs;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claims 24 and 28, above.

<u>CLAIM 30</u>

TEXT OF CLAIM:

30. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage;

a plurality of LEDs coupled to the output of the power supply in at least two current paths, whereby the cessation of current through one current path due to single point failure does not prevent current flow through another current path;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claims 24 and 28, above.

<u>CLAIM 31</u>

TEXT OF CLAIM:

31. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage;

an LED array having an input connected to the output of the power supply;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claims 24 and 28, above. Note that the "LED array" in this case need not be one that provides for multiple current paths.

CLAIM 32

TEXT OF CLAIM:

32. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the

rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

a plurality of LEDs coupled to the power supply output and having multiple current paths for dissipating power and emitting light;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claims 24 and 28, above.

CLAIM 33

TEXT OF CLAIM:

33. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the

rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

a plurality of LEDs electrically configured such that the failure of a single LED results in continued emission of light from a substantial number of the rest of the plurality of LEDs;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claim 24, above.

<u>CLAIM 34</u>

TEXT OF CLAIM:

34. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

a plurality of LEDs coupled to the output of the power supply in at least two current paths, whereby the cessation of current through one current path due to single point failure does not prevent current flow through another current path;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claim 24, above.

<u>CLAIM 35</u>

TEXT OF CLAIM:

35. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

an LED array having an input connected to the output of the power supply;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

EXAMINER'S REJECTION: See discussion of claim 24, above.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of claim 24, above. Note that the "LED array" in this case need not be one that provides for multiple current paths.

CLAIM 37

TEXT OF CLAIM:

37. The assembly according to claims 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 or 35 wherein the switchmode power supply comprises an integrated circuit power supply.

EXAMINER'S REJECTION: See discussion of referenced independent claims.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of referenced independent claims.

CLAIM 38

TEXT OF CLAIM:

38. The assembly of claim 37 wherein the integrated circuit power supply comprises a power factor correcting switchmode converter integrated circuit.

EXAMINER'S REJECTION: See discussion of referenced independent claims.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of referenced independent claims.

CLAIM 40

TEXT OF CLAIM:

40. The assembly according to claims 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 or 35 further comprising a conflict monitor compatibility circuit, wherein the LEDs provide a high impedance condition in the presence of leakage currents, and the conflict monitor compatibility circuit includes:

a transistor coupled to the LEDs and biased as a switch that switches from an essentially nonconductive condition in the absence of the high impedance condition to an essentially conductive condition in the presence of the high impedance condition; and

a low impedance load in series connection with the transistor and in parallel connection with the LED load,

whereby leakage currents are shunted through the low impedance load, ensuring compatibility with conflict monitors designed for incandescent bulbs.

EXAMINER'S REJECTION: See discussion of referenced independent claims.

In addition, the Examiner states, "Hildebrand discloses that it is known in the art to provide the use of an adaptive clamp circuit used to help control leakage currents by providing high impedance if such conditions exist. It would have been obvious to . . . provide an adaptive clamp circuit as taught by Hildebrand, in order to lessen the effects of current leakage inherent to LED circuitry and have a more dynamic response to this recurring problem."

This excerpt suggests the Examiner does not understand the problem solved by claim 40 (and claim 44, below), or the nature of the claimed solution.

"Lessening the effects of current leakage inherent to LED circuitry" does not make sense in this context. Perhaps the Examiner does not realize that the source of the problem leakage currents addressed in this claim is the solid state traffic switch commonly at the side of the road, not the "LED circuitry" in the traffic signal.

"Controlling leakage currents by providing high impedance" also does not makes sense. Leakage currents are not "controlled," but rather shunted away from the LED load in the claimed solution. And the claimed mechanism for doing this is a "low impedance load," not what the Examiner calls "providing high impedance."

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of referenced independent claims.

A separate reason for patentability is that the Examiner appears to be comparing the prior art to limitations from cancelled claim 5, rather than current claim 40. Claim 40 does not call out an "adaptive clamp," but rather a series of structural limitations directed to a very specific transistor and load configuration in a conflict monitor compatibility circuit. The Examiner's rationale for rejecting claim 40 refers to the relatively broad "adaptive clamp" concept that is not part of the claim, instead of focusing on the actual structural limitations. The Examiner has also apparently not considered that invalidated claims 5 and 6 were written in means-plus-function form, and thus gained additional breadth through section 112, paragraph 6, equivalency. Several limitations of relatively ***narrow*** claim 40 are absent from

Hildebrand as follows, and suggested nowhere in the art:

(1) The Examiner has not identified a single transistor in Hildebrand coupled to LEDs (see discussion of claim 24, showing Hildebrand lacks LEDs).

(2) The Examiner has not identified a single transistor in Hildebrand "biased as a switch." Hildebrand is crystal clear that its "dynamic load circuit" is an amplifier, and thus necessarily lacks a transistor-switch. (See 1:49-51: "a two stage inverting D.C. amplifier with a low impedance load and a defined offset voltage;" 6:17-50: "a grounded emitter high gain inverting stage," "closed loop gain of the amplifier," "amplifier output voltage.").

(3) The Examiner has not identified the presence in Hildebrand of the claimed ***functional*** characteristics of the claimed transistor, even if one substituted Hildebrand's neon or fluorescent lamp for the claimed LEDs. Namely, the Hildebrand circuit does not become "essentially nonconductive" with the absence of a high impedance condition at its neon/fluorescent lamp. Put another way, the ***claimed*** functional condition of claim 40 ***requires*** essentially no power dissipation through the pertinent shunt resistor when the signal LEDs are turned on. In sharp contrast, since Hildebrand discloses a negative impedance amplifier rather than a transistor biased as a switch, Fig. 4 of Hildebrand shows there is significant power dissipation at signal operating voltages, 80 to 135 VAC, particularly at the low end of the operating range. Hildebrand thus clearly lacks the functional limitation of an "essentially nonconductive condition in the absence of the high impedance condition."

CLAIM 41

TEXT OF CLAIM:

41. The assembly according to claims 24, 25, 27, 28, 29, 30, 32, 33 or 34 wherein the plurality of LEDs comprise a plurality of series-parallel connected LEDs arranged in strings.

EXAMINER'S REJECTION: See discussion of referenced independent claims.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of referenced independent claims.

CLAIM 42

TEXT OF CLAIM:

42. The assembly according to claim 42 wherein the plurality of LEDs comprise a ballast resistor in each string.

EXAMINER'S REJECTION: See discussion of referenced independent claims.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of referenced independent claims.

In addition, nowhere has the Examiner pointed to any art teaching or suggesting the ballast resistors of claim 42.

CLAIM 43

TEXT OF CLAIM:

43. The assembly according to claims 26, 31 or 35 wherein the LED array comprises a ballast resistor in each string of the array.

EXAMINER'S REJECTION: See discussion of referenced independent claims.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion of referenced independent claims.

In addition, nowhere has the Examiner pointed to any art teaching or suggesting the ballast resistors of claim 42.

CLAIM 44

TEXT OF CLAIM:

44. A conflict monitor compatibility circuit for use in traffic and pedestrian signaling applications, comprising:

an LED load providing a high impedance condition in the presence of leakage currents from a solid state traffic controller switch;

a transistor coupled to the LED load and biased as a switch that switches from an essentially nonconductive condition in the absence of the high impedance condition to an essentially conductive condition in the presence of the high impedance condition; and

a low impedance load in series connection with the transistor and in parallel connection with the LED load,

whereby leakage currents are shunted through the low impedance load, ensuring compatibility with the conflict monitors designed for incandescent bulbs.

EXAMINER'S REJECTION: See discussion of claim 40.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: Claim 44 is the independent version of the limitations of dependent claim 40. It thus stands as a broader invention in that it recites a conflict monitor compatibility circuit without regard to the specific type of LEDs or power supply used.

The discussion above with respect to claim 40 clearly shows as well that claim 44 is patentable over Hildebrand and all other art of record.

CLAIM 45

TEXT OF CLAIM:

45. An apparatus for supplying power to an LED array in an outdoor line-connected signal comprising:

a rectifier (32) having an input and an output, said rectifier (32) being responsive to power at said input for generating rectified power at said output;

a power factor correction converter (38) having an input connected to said output of said rectifier (32) and an output, said power factor correction converter (38) being

responsive to said rectified power at said power factor correction converter input for generating one of constant current and constant voltage at said power factor correction converter output;

an LED array (12) having an input connected to said output of said power factor correction converter (38) for receiving said one of said constant current and constant voltage to illuminate said LED array (12);

an electromagnetic interference filter means coupled to the power factor correction converter for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the rectifier (32), power factor correction converter (38) and LED array (12).

EXAMINER'S REJECTION: See discussion with respect to claim 24.

REASONS WHY THE REJECTION SHOULD BE WITHDRAWN: See discussion with respect to claim 24.

REJECTIONS DIRECTED TO THE REISSUE OATH

The rejection based on the reissue oath should be withdrawn, since the originally stated "reissue error" is a proper one under 37 CFR 1.175(a)(1) and MPEP § 1414, regardless of the applicability of the corrective action taken by the patent owner.

The original "reissue error" stated in Peter Hochstein's August 24, 1999 declaration

was claiming of less than the inventor had a right to claim in the original patent. Mr. Hochstein states in his reissue declaration:

> As one example, my original patent included claims 5 and 6, which are dependent claims directed to an adaptive clamp/conflict monitor compatibility means for solving leakage current problems. . . . I have added a claim directed to a conflict monitor compatibility circuit as an independent claim that is still distinct from and nonobvious over defendants' most pertinent prior art, the Hildebrand '601 patent. At the time I filed my original patent application, I erred by not realizing that I was entitled to independent claim directed to a conflict monitor compatibility circuit that did not have limitations directed to a particular power supply structure.

The "corrective action" Mr. Hochstein refers to above relates to independent claim 44, which calls out a conflict monitor compatibility circuit as an independent claim. The foregoing clearly recites a proper reissue error. MPEP § 1414 refers back to for a listing of proper reissue errors. MPEP § 1402 includes claiming too narrowly or too broadly as the first in the list of *proper* reissue errors.

The Examiner has no basis to consider this declaration "defective" merely because he finds fault with Mr. Hochstein's corrective action (namely, by rejecting claim 44). Indeed, Mr. Hochstein was not even required to explain what his corrective action was, as evident from this quotation from MPEP § 1414:

> In identifying the error, it is sufficient that the reissue oath/declaration identify a single word, phrase, or expression in the specification or in an original claim, and how it renders the original patent wholly or partly inoperative or invalid. The corresponding corrective action which has been taken to correct the original patent need not be identified in the oath/declaration. If the initial reissue oath/declaration "states at least one error" in the original patent and, *in addition*, recites the specific corrective action taken in the reissue application, the oath/declaration would be considered acceptable, even though the corrective action statement is not required.

Even if the Examiner were correct that finding fault with the corrective action provides a basis for considering the reissue declaration to be defective, the Examiner was clearly wrong to reject claim 44. Thus, since claim 44 is properly considered to be allowable over the art of record, there is no reissue declaration "defect" under any view of the applicable requirements.

For these reasons, the rejection for a "defective" reissue declaration should be withdrawn.

CONCLUSION

As shown above, the Examiner should reinstate the allowance of all pending claims. The prior art of record does not teach or suggest the claimed inventions, and the reissue declaration is not defective.

Accordingly, it is respectfully submitted that the Application, as amended, is now presented in condition for allowance, which allowance is respectfully solicited. Further and favorable reconsideration of the outstanding Office Action is hereby requested.

Respectfully submitted

HOWARD & HOWARD ATTORNEYS, P.C.

Date 6/16/03

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CERTIFICATE OF MAILING

I hereby certify that this **RESPONSE TO OFFICE ACTION DATED JANUARY 15, 2003** and attached **REQUEST FOR 2 MONTH EXTENSION OF TIME** for Serial Number **09/382,702** which was filed on **August 24, 1999** is being deposited with the United States Postal Service as First Class Mail, postage prepaid, in an envelope addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Anne L. Kubit

Anne L. Kubit

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APPENDIX EXHIBIT J

CLAIMS

24. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and having a power supply output;

a plurality of LEDs coupled to the power supply output and having multiple current paths for dissipating power and emitting light;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

25. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and having a power supply output;

a plurality of LEDs coupled to the output of the power supply in at least two current paths, whereby the cessation of current through one current path due to single point failure does not prevent current flow through another current path;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

26. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and having a power supply output;

an LED array having an input connected to the output of the power supply;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

27. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and having a power supply output;

a plurality of LEDs electrically configured such that the failure of a single LED results in continued emission of light from a substantial number of the rest of the plurality of LEDs;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

28. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage;

a plurality of LEDs coupled to the power supply output and having multiple current paths for dissipating power and emitting light;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

29. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage;

a plurality of LEDs electrically configured such that the failure of a single LED results in continued emission of light from a substantial number of the rest of the plurality of LEDs;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

30. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated

current output with respect to variations in the input line voltage;

a plurality of LEDs coupled to the output of the power supply in at least two current paths, whereby the cessation of current through one current path due to single point failure does not prevent current flow through another current path;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

31. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply coupled to the output of the rectifier for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage;

an LED array having an input connected to the output of the power supply;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

32. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

a plurality of LEDs coupled to the power supply output and having multiple current paths for dissipating power and emitting light;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

33. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

a plurality of LEDs electrically configured such that the failure of a single LED

results in continued emission of light from a substantial number of the rest of the plurality of LEDs;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

34. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

a plurality of LEDs coupled to the output of the power supply in at least two current paths, whereby the cessation of current through one current path due to single point failure does not prevent current flow through another current path;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

35. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage;

a rectifier coupled to the electrical input and having a rectifier output;

a current regulating switchmode power supply coupled to the output of the rectifier for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase;

an LED array having an input connected to the output of the power supply;

an electromagnetic interference filter means coupled to the power supply for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

37. The assembly according to claims 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 or 35 wherein the switchmode power supply comprises an integrated circuit power supply.

38. The assembly of claim 37 wherein the integrated circuit power supply comprises a power factor correcting switchmode converter integrated circuit.

40. The assembly according to claims 24, 25, 26, 27, 28, 29, 30, 31, 32, 33,

34 or 35 further comprising a conflict monitor compatibility circuit, wherein the LEDs provide a high impedance condition in the presence of leakage currents, and the conflict monitor compatibility circuit includes:

a transistor coupled to the LEDs and biased as a switch that switches from an essentially nonconductive condition in the absence of the high impedance condition to an essentially conductive condition in the presence of the high impedance condition; and

a low impedance load in series connection with the transistor and in parallel connection with the LED load,

whereby leakage currents are shunted through the low impedance load, ensuring compatibility with conflict monitors designed for incandescent bulbs.

41. The assembly according to claims 24, 25, 27, 28, 29, 30, 32, 33 or 34 wherein the plurality of LEDs comprise a plurality of series-parallel connected LEDs arranged in strings.

42. The assembly according to claim 41 wherein the plurality of LEDs comprise a ballast resistor in each string.

43. The assembly according to claims 26, 31 or 35 wherein the LED array comprises a ballast resistor in each string of the array.

44. A conflict monitor compatibility circuit for use in traffic and pedestrian signaling applications, comprising:

an LED load providing a high impedance condition in the presence of leakage currents from a solid state traffic controller switch;

a transistor coupled to the LED load and biased as a switch that switches from an essentially nonconductive condition in the absence of the high impedance condition to an essentially conductive condition in the presence of the high impedance condition; and

a low impedance load in series connection with the transistor and in parallel connection with the LED load,

whereby leakage currents are shunted through the low impedance load, ensuring compatibility with the conflict monitors designed for incandescent bulbs.

45. An apparatus for supplying power to an LED array in an outdoor line-connected signal comprising:

a rectifier (32) having an input and an output, said rectifier (32) being responsive to power at said input for generating rectified power at said output;

a power factor correction converter (38) having an input connected to said output of said rectifier (32) and an output, said power factor correction converter (38) being responsive to said rectified power at said power factor correction converter input for generating one of constant current and constant voltage at said power factor correction converter output;

an LED array (12) having an input connected to said output of said power factor correction converter (38) for receiving said one of said constant current and constant

voltage to illuminate said LED array (12);

an electromagnetic interference filter means coupled to the power factor correction converter for preventing conducted interference from feeding back onto a.c. power lines connected to the electrical input; and

a traffic, pedestrian or rail crossing signal housing enclosing the rectifier (32), power factor correction converter (38) and LED array (12).